# STUDIES ON SOME ASPECTS OF MANGROVE ECOSYSTEM IN A TROPICAL ESTUARY

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BY

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# DECLARATION

I hereby declare that the thesis entitled "**Studies on some aspects of mangrove ecosystem in a tropical estuary**" is an authentic record of research carried out by me under the supervision and guidance of Dr. E.G. SILAS in partial fulfilment of the requirements of the Ph.D. Degree in the Faculty of Marine Science of the Cochin University of Science and Technology and that no part of it has previously formed the basis of the award of any degree, diploma or associateship in any University.

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# CERTIFICATE

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

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## C O N T E N T S



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# PREFACE

According to an estimate made in the early seventies, approximately 60-75% of the tropical coastline of the world is bordered with mangroves. The mangroves characterise a unique ecosystem endowed with great biological wealth, species richness and genetic diversity similar to the tropical rainforest system. The mangrove ecosystem derives its importance from the multiple function it performs and the variety of purposes for which it is utilized.

In a mangrove ecosystem the trees and shrubs form the basic component. These communities of salt tolerant intertidal vegetation with their peculiar morphological and physiological adaptations to thrive in muddy and swampy soils act as a protective barrier between land and sea. The mangrove ecosystem being an open one freely interacts with the adjoining terrestrial and marine systems. Mangroves provide shelter and abundant food to a variety of mammals, birds, reptiles and aquatic fauna.

In particular, attention has been drawn to the ecological value of high production of plant detrital food in the system which is made use of by the larvae and juveniles of many species of crustaceans, molluscs and fishes. This helps in their recruitment to the inshore fisheries. The continuous flow of detrital food and particulate organic matter from the mangrove system into the coastal waters enriches the productivity of these waters.

The benefits derived by mankind from this ecosystem are many. Mangroves are considered as a life support system. Man's association with mangroves dates back to several centuries. The mangroves have provided rural population the forest derived products such as poles, timber, charcoal, tanning agents, dyes, resins, medication and animal fodder. Mangroves have also provided food items such as bird's eggs, edible fruits and honey. The mangrove waters have supported sustenance capture and captive fisheries and the total production from these activities are estimated to be over one million tonnes (Silas, 1987).

Mangroves have to be appreciated as an important component of the coastal zone and their functions and utility have to be recognised. The mangrove vegetation helps in the consolidation of muddy substratum, prevents soil erosion protects the coastal population against the fury of storms, cyclones and floods. They provide them with direct and indirect amenities such as waste water disposal, recreation and sport fishing.

However, instead of realizing the importance of mangroves, they have been indiscriminately exploited for immediate gains and to meet the demands of a steady increase in population especially in the developing countries. Large areas occupied by mangroves have been degraded for agricultural purposes by construction of dykes for conversion as paddy fields. During the last 30-40 years the depletion in the extent of mangrove areas has attained alarming proportions mainly through deforestation, conversion of mangrove land for agriculture, salt production, aquaculture, human settlements, industrial estates and similar activities.

In particular, the situation in the backwaters of Kerala, which reportedly had about 70,000 ha of mangroves, is unique in the sense that there has been a total conversion to other uses such as paddy cultivation, coconut plantation, aquaculture, harbour development and urban development

In order to save and restore what is left over national and international organisations are mounting pressure on scientists and policy makers to work out ways and means conserving and managing the mangrove ecosystems.

In this context, it has been observed in recent years that mangrove vegetation has remained intact in isolated pockets of undisturbed areas in the Cochin estuarine system and also that there is resurgence of mangroves in areas of accretion and silting. The candidate took up the present study with a view to make an inventory of the existing mangrove locations, the areas of resurgence, species composition, zonation and other ecological parameters to understand their dynamism and to suggest a mangement plan for this important coastal ecosystem.

## A C K N O W L E D G M E N T

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# 1. INTRODUCTION

# INTRODUCTION

The mangrove forests, which are characteristic of tropical coastal areas, form an ecosystem dominated by several speies of peculiar, salt tolerant, trees and shrubs in a relatively harsh environment and where many species of animal kingdom also find shelter. This curious ecosystem had not received due attention of the scientists until a few years ago. The traditional dwellers of mangrove areas have been, however, aware of the benefits and utility of the mangroves forests and their fauna and flora. Recognisable descriptions of mangroves were made by the Greeks as early as 325 BC.

According to Vannucci (1989) the word 'Mangrove' designates an ecosystem formed by a very special association of plants and animals that live in the intertidal area of low lying tropical coasts, estuaries, deltas, backwaters and lagoons. It is also used to designate the trees and shrubs that grow in the intertidal environment.

The Oxford Dictionary has stated that the English word 'mangrove' (1613) has been derived from the Portuguese word mangue or the Spanish word mangle in association with the English word 'grove'. Thus 'mangrove' means a grove made of mangle or mangue. Vannucci (1989) who has made an indepth study on the word mangue, has stated that historical records and navgation charts prepared by the Portuguese indicate this word since early fifteenth century and that the word could be further traced back to it's possible origin in West African countries. The word 'mangal' is also Portuguese and has been used to designate extensive mangroves.

The definition of mangroves has been debated very much. Macnae (1968) defined 'mangroves' as 'trees and bushes growing between the level of high water of spring tides and a level close to but above the mean sea level'.

Various authors, Chapman (1976) Bunt et al. (1982) and Saenger et al. (1983) have admitted the difficulties involved in defining the mangrove and the differences of opinion on the same. Schimper (1907) defined mangroves as the plant associations present in the intertidal zone between the high and low tide marks. On the other hand Davis (1940) stated that mangroves occur above and below the intertidal zone as well and on coasts where there are no tides at all. Du (1962) considers mangroves as an ecological group of plants belonging to several families but having similarity in their physiological and structural adaptations to a saline habitat especially along sheltered tropical coasts.

In a little more elaborate manner Aubreville (1970) defined mangroves as 'coastal tropical formations found along the border of seas and lagoons, reaching upto the edges of rivers to the point where the water is saline, growing in swampy soil and covered by sea during high tides. The back mangroves are reached by sea water only at very strong tides.

Odum et al. (1982) stated that the term mangrove refers to 'halophytic' species of trees and shrubs. This definition encompasses more than 50 species of tropical trees and shrub which are adapted to thrive on wet soils and saline habitat. The plants usually have a degree of vivipary and produce propagules.

Macnae (1968) used the word 'mangrove' for individual kind of trees and the word 'Mangal' for the whole community comprising of different species of mangrove plants.

Globally mangrove ecosystems are believed to contain about 70 species of trees and shrubs and more than 20 additional species which are frequently associated with mangroves. (Hamilton and Snedacker, 1984).

Several geological and other factors have made the Indo-Pacific as the cradle of speciation. In this area as many as 70 species have been described as tropical mangroves meaning that they are to be found exclusively in mangrove swamps. The number of species to be considered as mangroves are still being discussed. The most common species that are found in association with tropical mangroves are those of Terminalia, Hibiscus, Thespesia, Casuarina, some legumes, Barringtonia, Salicornia, Arthrocnemum, Ipomoea and Sesuvium.

While the mangrove trees and shrubs form the permanent community it is estimated that the mangrove environment provides living space for a dependent biota of more than 2000 species which include fishes, invertebrates and epiphytes (UNESCO/IUCN, 1984). Saenger (1983) has given a list of species of biota recorded from different geographical regimes The Asian region is reported to have the following number of species:-

Bacteria-10, Fungi-25, Algae-65, Bryophytes-35, Monocots-73, Dicots-110, Crustaceans-229, Molluscs-211, Echinoderms-7, Fishes-283, Reptiles-22, Birds-17 and Mammals-36.

The above figures indicate the species richness and diversity in the mangrove ecosystems.

The major importance of mangrove lies in the variety of functions they perform and their utility. There is also a wide range of direct and indirect products which are utilized by the coastal communities to sustain their economic activities. UNESCO (1984) has catalogued their uses and these can be classified as follows:

Fuel: fire wood for cooking, heating, burning bricks, charcoal, alcohol.

Construction material - Timber for scaffold, piling, construction of rail road, boat building material, thatching material.

Fishing - poles for fishing and trap, fishing boats, masts, fish poison, tannin for net preservation.

Textiles - Synthetic fibres, rayon, dye, tannin for leather leather products.

Food, beverages - Sugar, alcohol, cooking, vinegar, fermented derivates.

Household - Furniture, tools, toys, match sticks, incence, matress.

Agriculture - Fodder, Green mannure.

Other related produce -fish, prawn, shell fishes as food, honey, wax, birds, reptiles, mammals (food, recreation etc.)

The list above shows that the number and variety of known uses and products from the forests are many. Each plant species is utilized for a variety of purposes that vary from region to region and may be localized. Traditionally mangroves have been utilized as a multiple use system in a small scale, and it has been sustainable.

In spite of all these important uses of mangroves, there are still increasing pressure for conversion of mangroves for agriculture and aquaculture. Such human pressure has lead to loss of mangroves on a large scale. Phillippines lost about 24,000 ha per year between 1967 and 1975. This kind of destruction in many countries has lead to elimination of protection to coastal zone, elimination of renewable sources of energy, elimination of biological species diversity. These in turn affect the socio economic condition and livelihood of people depending on the mangrove forests.

However, in recent years, the importance of mangrove ecosystem is being realized and national and international organisations are encouraging conservation and management measures.

# REVIEW OF LITERATURE

Mangroves have aroused the interest and curiosity of mankind from the earliest times for various purposes, whether it was for utilizing them for the forest products they yield or the fisheries they support or to broaden our knowledge about them through scientific studies. As a result of this curiosity and growing interest on mangroves the literature has steadily increased to over 7000 titles. Literature relevant to the present study are briefly presented here, under different heads.

## DISTRIBUTION AND EXTENT OF MANGROVES

Mangroves commonly occur throughout the range of humid tropics on sheltered coasts having soft, muddy intertidal substratum. To a limited extent they also occur in the subhumid tropics. Various authors have given their appraisal on the extent and distribution of mangroves along different coasts (MacGill, 1959; Macnae, 1968; Chapman, 1970, 1975; Pannier, 1977, MacIntosh, 1982, Blasco, 1984 and Vannucci, 1989). While reviewing the latitudinal limits of mangroves MacIntosh (1982) reports that in the northern hemisphere, mangroves extend to about 27° to 32°N and in the southern hemisphere to about 32-38°S. The extreme southerly limit is reported to be Corner Inlet (38°45'S) on the Coast of Victoria, Australia. Within these latitudinal limits, mangroves are absent in certan coasts such as those of Peru and Chile due to unfavourable oceanographic conditions such as the cold Western boundary current which flows northwards to lower latitudes along the coast (Vannucci, 1989).

Considering the geographical distribution of mangrove forests two groups are distinguished viz., (i) the Indo-west Pacific group - consisting of East Africa, Red Sea, India, Southeast Asia, Southern Japan, the Philippines, Australia, New Zealand and the Pacific islands east of Samoa and (ii) the New World - West African Group consisting of Atlantic coasts of Africa and both Americas, Gulf of Mexico, Pacific Coast of Tropical America and the Galapago islands (Chapman, 1976; 1977). (Fig. 1).

Though circumtropical in distribution, mangroves grow in luxuriance in the Indo-west Pacific region where the extent of mangrove area is estimated to be about 10 million ha (Rabanal, 1976). The following table gives the areal extent of major mangroves formations along different coasts in this region.

| Country | | Mangrove area ($x 10^6$ ha.) | Country | | Mangrove area ($x 10^6$ ha.) |
|---|---|---|---|---|---|
| Indonesia | - | 3.60 | Papua New Guinea | - | 0.41 |
| Australia | - | 1.16 | Sabah | - | 0.37 |
| Bangladesh | - | 0.60 | India | - | 0.36 |
| Burma | - | 0.52 | S. Vietnam | - | 0.29 |
| Thailand | - | 0.60 | Pakistan | - | 0.25 |
| Phillippines | - | 0.40 | Sarawak | - | 0.17 |
| | | | Malaysia | - | 0.15 |

In other coasts, extent of mangroves range from 2800 ha. (Singapore) to 85,000 ha in Mozambique. (Source MacIntosh, 1982).

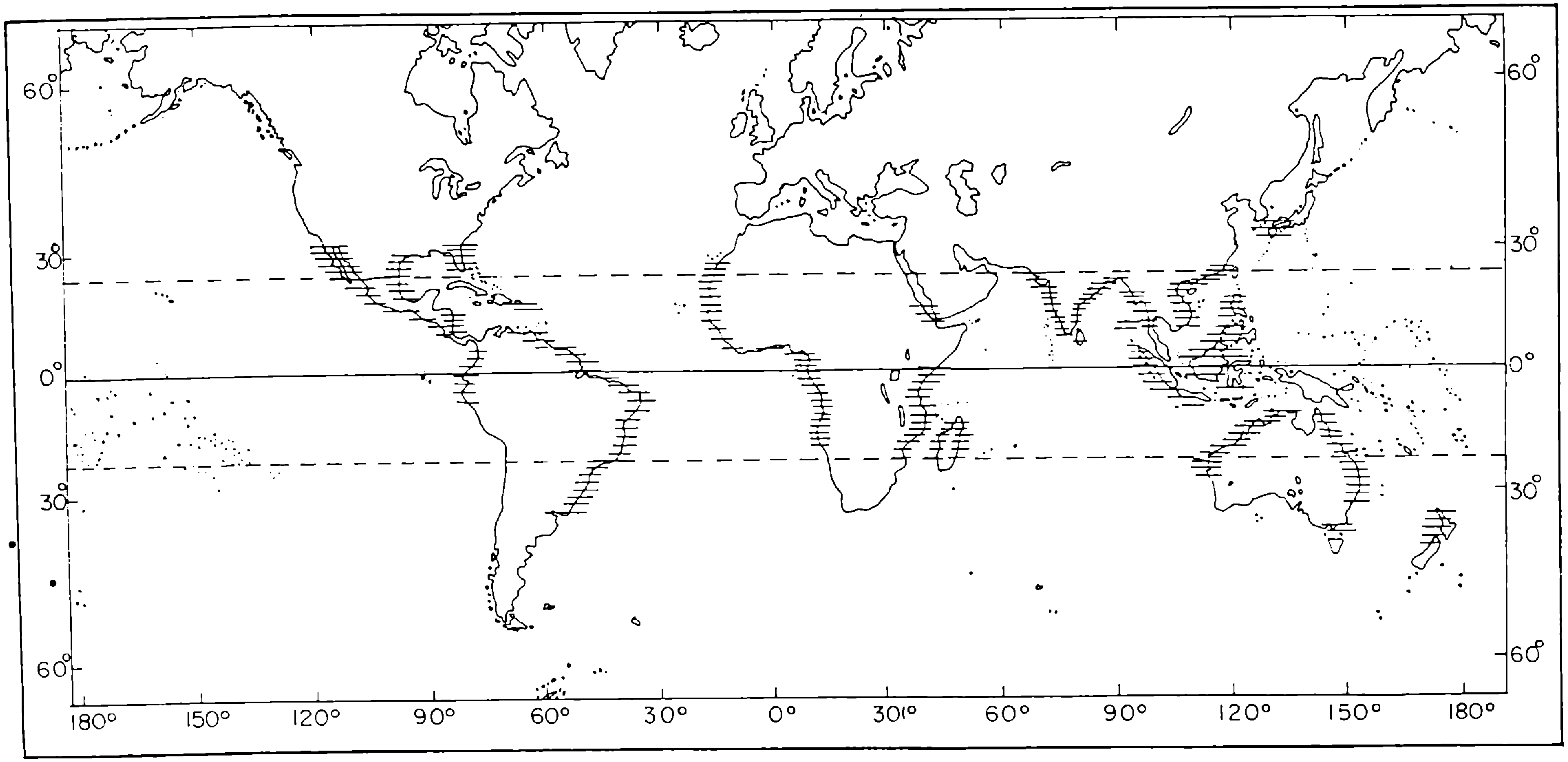



**Fig. 1.** World distribution of Mangroves

## LIMITING FACTORS FOR DISTRIBUTION OF MANGROVES

Mangroves have adapted themselves to withstand wide range of harsh abiotic factors and are capable of establishing themselves even on coral reef flats and sand spits but development of extensive mangrove forests seem to depend on certain limiting factors.

While soil salinity, soil structure and hydrology are considered as the main agents controlling the distribution of mangroves, the importance of climatic conditions as a limiting factor is drawn attention to by MacIntosh (1982), Blasco (1984) Koteswaram (1986) and others.

### Temperature and rainfall

Mangroves thrive best in areas where the average minimum monthly temperature is above 20°C with an annual range not exceeding 5°C (Van Steenis, 1962). Macnae (1963) observed the presence of mangrove only in regions where the average air temperature is not below 19°C and the average minimum air temperature is not below 13°C. Chapman (1976) has reported that mangroves are killed at the northern latitudinal limits during severe winters, Chapman has also reported that the most cold tolerant species is *Avicennia marina* var *resinifera* occurring at Aukland (37°S).

Pannier (1972) and Tomilson (1978) have stated that the number of species of mangroves declined from thirty in the Indo-Malesian region to one in the Red Sea Coast of Africa due to extreme aridity.

Mangrove forests seem to be abundant and well developed in areas of high and non-seasonal rainfall. Analysing the global distribution of mangroves, Blasco (1984) stated that while atmospheric temperature sets the latitudinal distribution of halophytes, the regional rainfall and evapo-transpiration rates exercise profound influence on mangrove soils and pedogenesis. These factors have direct biological implications. He further suggested that each mangrove ecosystem must be characterised by its climatic identy card. He also stated that tall, dense and floristically diverse mangroves were almost confined to tropical summer rainfall zone and thickets of low scattered species occurred in subtropical and warm temperate climates.

Coastal exposure

Most extensive mangrove formations occur in the Indo-west Pacific region along the coastline protected from strong wave action and climatic forces such as hurricanes and also where the seas are generally calm and the rivers wash large quantities of silt into the coastal zone.

Approximately 1/5 of the World's mangroves border the shallow seas of Sunda shelf region enclosed by Vietnam, Gulf of Thailand, Malaysia, Sumatra, Java and Borneo. In other countries, mangroves are developed in estuarine and delta environments mostly. The Irrawadi and Gangetic deltas contain about 1 million ha. (MacIntosh, 1982). There are also extensive mangrove areas in Eastern Africa, Papua, New Guinea and Australia.

## Substratum

Mangroves flourish on fine alluvial muds composed predominantly of silt and clay particles. These soft substrata provide essential anchorage for young seedlings while their root systems are developing, and they retain moisture efficiently. MacIntosh (1962) reported that mangrove clay soils bordering the Selangor estuary (Peninsular Malaysia) retained more than 31 per cent water by weight even in fully unshaded areas exposed to evaporation continuously for ten days.

It has been observed that mangroves promote shore accretion by accelerating the rate of sedimentation. The pneumatophores of species such as Avicennia are specially effective in trapping sediments. High rate of mangrove shore progression have been documented, such as a rate of 125 m per year estimated for South east coast of Sumatra at Pelambang (Macnae, 1968).

## FLORA

In mangrove literature floristic studies out weigh the contribution on other aspects. Chapman (1970) recognised 53 species as typical mangrove vegetation, out of which 42 belong to the Old World region where species diversity is greater. Mangrove vegetation belonging to at least 17 different families exhibit various kinds of morphological and physiological adaptations to survive in the harsh intertidal environment. Classical examples of these biological adaptation are extensively documented (e.g. Macnae, 1968, Walsh, 1974).

The mangroves derive their unique appearance through some of these morphological adaptations. The most striking feature described in literature often is the root system in mangroves. The aerial roots proper, butress roots, pneumatophores and knee roots which are above ground help the trees to anchor themselves in the soft substratum. Extensive cable roots and anchor roots (as in Avicennia) perform the same function. The aerial roots, pneumatophores and lenticels on the tree bark facilitate exchange of gases to the inner tissue. This is essential for the plants which are rooted in anaerobic soils. Vivipary, in the sense that the seeds germinate while still attached to the mother plant is another important adaptation in most mangrove species. Recently Tomilson (1986) has extensively described these adaptations. Hutchings and Saenger (1987) have also recently reviewed our knowledge on the adaptations of mangrove flora and fauna to their environment.

Karmarkar (1985) has reviewed some of the physiological adaptations exhibited by mangrove plants. They are endowed with an ion influx-efflux regulatory mechanism by virtue of which they regulate their cellular ionic contents. Walter (1961) classified the mangroves into three types viz., Salt excluding, Salt excreting and Salt accumulating. Members of Rhizophoraceae are included in the first category where their root system possesses an ultra filtration mechanism. Species of Avicennia, Aegiceras and Acanthus which are salt excreting, regulate internal salt levels through foliar glands. Species of Sonneratia, Lumnitzera, Excoecaria, Sesuvium and Suaeda are reported to accumulate high concentrations of salt in their tissues and they develop succulence.

Clough (1985) discusses various aspects of photosynthesis, water loss and salt balance in mangroves. According to him a number of mangrove species grow best at salinities between 4 and 15‰. Persistant cloudiness, evenly distributed rainfall are considered to have synergistic effect on photo synthesis and plant growth.

Several aspects of physiology of salt tolerant plants and on photosynthesis in mangroves have been investigated by Bhosale (1974, 1982 and 1985).

Floristic details of the famous Pichchavaram mangroves of South India have been given by Blasco (1975); Krishnamurthy et al. (1978; 1984; 1985).

Mangrove vegetation usually exhibit characteristic zonation in relation to contour and level of shores (which determines the frequency and duration of tidal inundation) and a number of other factors; notably the degree of water logging of the soil and the soil water salinity (Macnae, 1966; Clarke and Hannon, 1969, 1970). Mangrove zonation is distinct on shores with a tidal range of several metres. As in the west coast of Peninsular Malaysia where a classification of mangrove vegetation types in relation to the frequency of tidal inundation was established more than 60 years ago (Watson, 1928). Zonation was observed to be complete upto the landward limit of the tidal penetration, only in areas receiving high and non-seasonal rainfall. Elsewhere, as on some parts of the Queensland coast where annual rainfall is only 750-1000 mm, the arid upper shore may be completely devoid of mangroves (Macnae, 1966).

As regards seral characteristics of the major vegetation types, MacIntosh (1982) states that, species of Avicennia and Sonneratia are consistently the pioneer mangroves on coastal depositional shores in the Indo-Pacific region. Avicennia seedlings are able to colonise soft, semi-fluid mud flats down to about mid-tide level. Typically a pioneer zone of Avicennia and Sonneratia extends from this seaward limit to around mean high water of neap tides. These pioneer vegetation types create conditions favourable to other mangrove species like Rhizophora to colonise. Bruguiera species replace Rhizophora towards the landward margin reached only by exceptionally high spring tides. Where the substratum is well drained, other mangrove trees such as Excoecaria and Xylocarpus may be common. Species of Ceriops, Lumnitzera and Aegiceras are typical colonisers of open shore habitats.

In more estuarine localities Rhizophora usually replaces Avicennia and Sonneratia as the pioneer mangrove. Upstream and towards other zone of freshwater influence, mangroves are replaced gradually by other vegetation communities dominated by nypa palm (South East Asia), Heritiera (Bay of Bengal) of Barringtonia (Eastern Africa). Zonation seems to be less complex among the mangrove communities of the New World and West Africa due to limited number species of Avicennia, Rhizophora, Conocarpus and Laguncularia.

Rabinowitz (1978) suggested that size, shape, weight, buoyancy etc. of propagules and their differential sorting by tides may be responsible for mangrove zonation. According to Odum (1982), in some sites species zonation does not appear to represent seral stages of succession, Blasco (1984), stated that zonation and seral succession of mangrove vegetation were related to complex local factors such as hydrology and climate.

## Community structure

The community structure of mangrove forests is influenced by many biotic and abiotic factors (Mall et al., 1985). Since abiotic factors vary widely over geomorphic regions, mangrove stands exhibit inter regional and local variations, in structural characteristics. (Sukardjo et al., 1984). Cintron and Novelli (1984) have mentioned that species diversity is higher where there is greater variation in community structure. Lugo and Snedaker (1974) developed a classification scheme for mangrove community based on tidal and hydrological factors.

This classification was modified by Cintron et al. (1980) who recognised 3 general types viz., (riverine), (fringe and over wash) and (basin). According to them, dwarf, scrub and hammock are special seral types responding to local geological and edaphic conditions. Pool et al. (1977) studied structural characteristics and correlated local variations to edaphic factors. Some species dominate certain localities. Complex relationships exist between community structure and major forces such as tides, nutrients, water quality and edaphic factors. A study of community structure is very important for management of mangroves for ensuring sustainable yields (Saenger et al., (1983).

## HYDROGRAPHICAL PARAMETERS

Mangroves are facultative halophytes and require saline water to reduce competition from other terrestrial and vascular plants (Kuenzler, 1974). According to UNESCO (1979) mangroves grow and flourish well in places where there is constant variations in salinity. Different mangrove species have different optimum requirement. Clough et al., (1984) Burchet et al., (1984), and Karmarkar (1985) have stressed that mangrove waters must be diluted during wet season to allow mangrove species to have the optimum salinity. According to Odum et al.(1982) large scale variation in salinity is a characteristic feature of mangrove ecosystem and in most mangroves low saline conditions exist for longer periods.

Snedaker (1984) reported that freshwater input not only dilutes seawater but also gives nutrient inputs. He cautioned that changes in timing or quantity of fresh water may cause damage to mangroves. In the water, heavy run off may affect light pentration due to silt and suspended matter. Lugo et al. 1974, observed oxygen content below saturation point in the range 2-4 ppm often reach 0 condition in stagnant water. Heald (1971) and Odum et al., (1982) mentioned that turbidity was between 1 to 15 JTU due to presence of dissolved organic matter of high concentration.

### Nutrients

Mangrove ecosystem traps various micronutrients and elements. These elements are removed from water by the action of proproot, algae fine root system and micro algae.

Walsh (1967) studying seasonal variation in nutrients in Hawaii swamp stated that concentrations were low in mangrove waters. Snedaker and Lugo 1973 confirmed this point. Tundisi et al. (1973) reported only little variation in dissolved phosphate in Canania swamp in Brazil. Winata and Muktar (1982) reported that nutrients were high in Cilicap mangroves in Indonesia. Sukardjo (1982) reported that nitrogen content was high on the seaward side and the mangrove detritus was exported to adjacent waters, where they increase nutrient contents.

Saenger (1984) stated that concentration of dissolved nitrates, nitrites and phosphate were very high during monsoon season in a Thailand mangrove water. As regards tidal variations, high concentration of nutrients during low tide period was observed. (Bacon, 1967; Limpsaichol, 1984). Snadaker and Lugo (1973) hypothesised that terrestrial run off acts as main source of dissolved nutrients for mangrove waters.

Gotto and Taylor (1976) Gotto et al. (1981) reported that nitrogen fixation occur in mangrove waters at rates comparable to those measured in other shallow tropical marine areas. Mocko (1981) using stable nitrogen techniques found as much as 25% nitrogen in a Texas mangrove from nitrogen fixation.

Another source of nutrient in mangrove water is mineralisation of organic detritus derived from mangrove plants. Golley et al. (1962) and Odum and Heald (1975) showed that the degradation of mangrove litter constituted substantial amount of nutrients to the coastal waters Although many reports are available on the rate of decomposition of mangrove litter, none of these attempted to relate it to changes in nutrient contents in water bodies (Heald et al. 1979; Lugo et al., 1980). Studies of Aksornkoe (1982) revealed that main nutrients such as Na and Mg are not limiting factors in mangrove environment since they occur in large quantities in sea water. They consider phosphates and nitrates as limiting factors for both mangrove and phytoplankton production. Nixon et al. (1984) showed that there was no outwelling of nutrients from mangrove environment to adjacent water bodies. Ricard (1984) mentioned that nutrients other than inorganic forms may also play an important role in limiting plankton production in mangroves.

Alongi (1990) studied the effect of mangrove detrital outwelling on nutrient regeneration and oxygen fluxes in coastal sediments of the Central Great Barrier Reef lagoon. He found that organic carbon and total nitrogen concentration ranged from 0.2 to 3.9% and 0.01 to 0.18% by sediment dry wt. respectively and were highest at stations receiving greatest quantities of mangrove litter. Total concentration ranged from 0.013 to 0.048% by DW. but did not relate to outwelling. CNP ratios showed 39:17:1 at station receiving more litter and low at 29:6:1 receiving least litter.

Phytoplankton and algae

Micro algae play an important role in the production of any aquatic ecosystem. Phytoplankton can also be a major component of primary production in a mangrove ecosystem (Odum et al., 1982). However, Cooksey (1984) mentioned that little work has been published on planktonic and benthic algae of mangrove environment. Davis (1950) was first to publish a list of phytoplankton present in a mangrove environment. Teixeira et al. (1985), Tundsi et al. (1973) Kutner (1975) have carried out extensive studies on various aspects of planktonic populations of Canania swamps in Brazil.

A rich algal flora is also associated with mangrove environments. Mangrove algae are divisible into two main groupings,an epiphytic assemblage of macroscopic algae living on the stems, aerial roots and pneumatophores of mangrove trees, and an epiterrestrial community of predominantly micro-algae. It is these algal communities that provide the main feed source of fish and prawns in mangrove culture ponds.

Boto and Robertson (1990) studied the nitrogen fixation by algal mats and algae covering parts of mangroves such as prop roots in a tropical mangrove ecosystem in Australia and reported that 1 to 3.5% of nitrogen requirement for forest net primary production are contributed by these algae.

PRODUCTIVITY OF MANGROVE ECOSYSTEM

Lugo and Snedaker (1974) have reviewed the biological process operating in mangrove ecosystem to sustain their high levels of production. The energy linkage from vegetation to aquatic organism (fishes) are through the detritus based food chains. Biomass produed in mangrove forests are reported to exceed 20t/ha/yr (Christensen, 1978, Ong et al. 1979).

Mangrove leaf litter fall indicate an average annual resource of 6-8 t/ha. The flushing efficiency of the tides determine the quantity of detritus exported out of the mangrove area to coastal water. Studies carried out in Florida (Snedaker and Lugo, 1973; Odum and Heald, 1975) and in Thailand by Aksornkoe and Khemnark, (1980) indicated that the annual net export of mangrove plant litter into coastal waters averages about 50% of the total leaf fall. The various processes involved in decomposition of leaf litter and detritus formation and the range of commercially important species in fn fishes and shell fishes which are detritus feeders are elaborately discussed by MacIntosh (1982).

Gong and Wong (1990) estimated the total standing biomass of a managed mangrove forest in Malaysia as 8.26 x $10^6$ tonnes for a total area of 40,800 ha. The biomass released from the forest system was calculated as 55% in the form of dead trees, 39% small litter and 6% as slash. The amount of macronutrients (N, P, K, Ca, Mg and Na) released are 12,210, 11870 and 2690 tonnes through litter, dead trees and slash respectively. Using 50% as the quantity exported, the biomass and nutrients from leaf litter alone was estimated as 158300 and 5100 tonnes annually or 3.9 and 0.1 tonnes/ha/year respectively.

## FAUNA

The mangrove swamp community includes a complex assemblage of resident, semi resident and visiting species. Species of gastropods and brachyuran crabs dominate the intertidal surface as they are adapted to withstand exposure to high temperature, desication and salinity fluctuations. The mud lobster, Thalassina, the mudskippers and frogs are common fauna in mangroves.

Macnae (1968) has given elaborate details about the fauna of Indo-Pacific mangrove forests. The wild life of Sunderban forests are described by Chaudhuri and Chakraborti (1989). The assessment of benthic fauna of Sagar islands in Sunderbans are presented by Chaudhury (1980). An exhaustive list of faunal communities dependent on mangrove swamps is given by UNESCO (1984).

Studies carried out in Florida, (Odum and Heald, 1972); Malaysia (Ong, 1978) India (Prince and Krishnamurthy, 1980) and New Guinea (Collette & Trott, 1980) have indicated that more than 100 species of fish visit the mangrove waters. About 50% of the fishes belong to demersal group. As regards Crustaceans Macnae, (1974) reported that mangrove swamps are utilized as nursery areas by juvenile stages of many species of commercially important species of prawns belonging to Penaeus, Metapenaeus groups and the fresh water prawn Macrobrachium.

Chong et al. (1990) studied the fish and prawn communities of four coastal habitats of Selangor, Malaysia. The mangrove community comprised predominantly of juvenile fish and prawns. Their study indicated that mangroves functioned as feedings grounds rather than nursery grounds of juvenile fishes, but it is a nursery ground for prawns.

Robertson and Duke (1990) reported that 25 species of fish accounted for over 96% of catch by numbers in a mangrove habitat in tropical

Queensland, Australia. He observed that only 5 species were permanent residents completing their life cycles in the mangrove swamps; 8 species were long term residents being present in mangroves for about an year and 7 species were short term users of mangroves. They also reported that recruitment into the system was seasonal and confined to late dry season (October) to mid wet season (February). Resident species constituted more than 90% of total fish numbers in August. It is of interest to note that only nine of the 20 species examined are strictly dependent on mangrove lined estuaries, the remaining 11 are captured in inshore areas. They state that only 4 out of the twenty species are of commercial importance in Australia and the rest form a good prey for several other commercially important species.

Fisheries and aquaculture importance

The linkages between mangrove ecosystem and coastal fisheries were demonstrated by Odum and Heald, ( 1975 ) Christensen, (1978) Ong et al., (1979) and others. The relations between extent of mangrove area and coastal fish production was established by Macnae, (1974 ) Martosubrato and Naamin, (1977 ). As the natural habitat for a variety of finfishes and shellfishes, mangrove areas have been preferred for traditional aquaculture practices and the rapidly developing semi-intensive and intensive farming methods in South Asian countries. These farming methods for various cultivable species have been reviewed in great detail by MacIntosh (1982).

Conservation and management aspects

Mangroves have been subjected to uncontrolled exploitation and degradation in the developing countries of the tropics. The need of the hour is to protect them, conserve them and manage them for sustainable economic benefits. These aspects have been reviewed by Vannucci (1985), Aksornkoe (1985) Krishnamurthy (1985), Silas (1987) and Vannucci (1989).

## STUDIES ON INDIAN MANGROVES

Historical references to the Indian mangroves in western literature have been cited by Vannucci (1989). Notable among them is a passage from Vergilius which says 'Ocean Himself generates forests in India.......... upto the end of the world' Another interesting referrence cited was about the plant, Excoecaria agallocha in Dioscorides (VI century A.D.)

Studies on botanical aspects of Indian mangroves started as early as seventeenth century by Von Rheede in this work, Hortus Malabaricus. The Sundeban mangroves were studied by Roxburgh (1814) in his famous work, Hortus Bengalensis. Sir Hooker's 'Flora of India' was published in 1885. More comprehensive accounts on Indian mangroves werre presented by Prain (1903), Blatter (1905), Cooke (1908), Gamble (1936), Champion (1936) and Griffith (1936).

Studies on mangroves of Bombay, including some ecological aspects, were made by Navalkar (1940), Navalkar and Bharucha (1948) and Navalkar (1951). Champion and Seth (1968) have dealt with the grouping, plant associations and classification of littoral and tidal swamp forests.

Various authors have attempted at estimating the extent of mangroves in the different regions along our coasts. Sidhu (1963) estimated the extent of mangroves in India as 7,00,000 ha wheras Blasco (1975) gave the estimate as 3,56,500 ha. Anon (1987) has given the area as 6740sq. km (Fig. 2).

The Sunderbans of India is estimated to extend to about 4170 sq. km and is considered as the largest single block of mangroves in the world. Recently Chaudury and Chakraboty (1989) have comprehensively reviewed the work done on Sunderban mangroves including ecological aspects, wild life and conservation aspects.

The luxuriant mangrove forests of Andaman and Nicobar islands have been studied by Mathuada (1957), Sahni (1959), Thothathri (1960) and Balakrishnan (1979). They observed that the islands represented a distinct biogeographical realm on account of rich endemism, geographical isolation and proximity to South east Asian countries. Mall et al. (1985) dealt with certain ecological aspects of mangroves occurring in various sites of the Andaman group of islands.

The mangroves of Orissa, especially those of Mahanadhi were studied by Haines (1921); Rao and Sastry (1974). The flora were observed to have similarity with those of Sunderbans in terms of species composition.

Mangroves of the Godavari delta region have been studied by Cornwell (1937), Waheed Khan (1959), Ganapati (1969), Rao and Sastry (1974) and recently by Azariah et al. (1990). Cornwell (1937) recorded all the three species of Avicennia viz. A. alba, A. offcinalis and A. marina in this area. Blasco (1975) observed that Rhizophoracea are becoming rare and that Sonneratia apetala is the dominant species in the river mouth region. Ecological aspects of mangrove forests of Godavari and Krishna estuaries have been investigated by Rao et al. (1985).

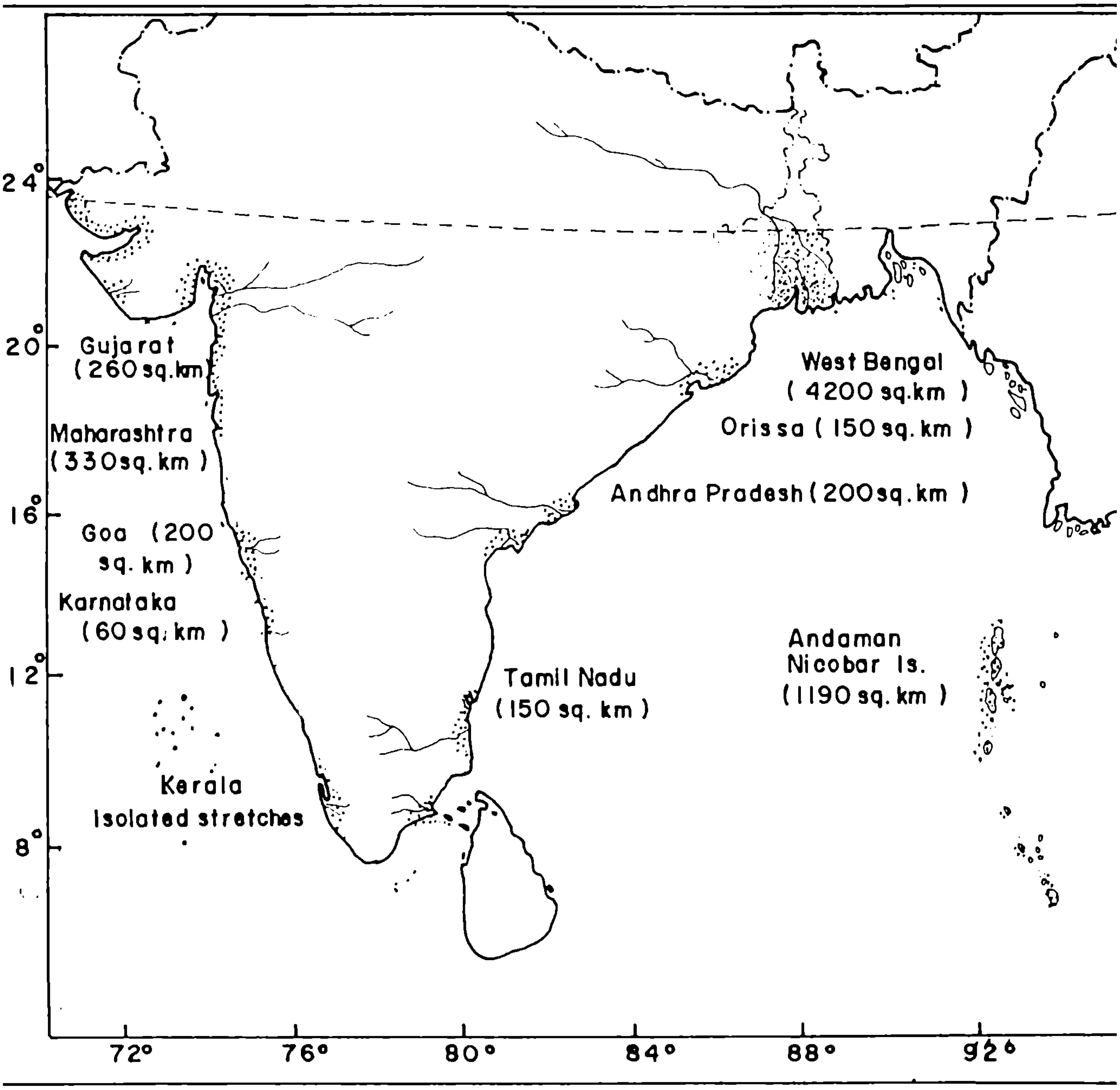



**Fig. 2.** Map showing the distribution of mangroves in India.

The famous Pichavaram mangroves of Cauvery delta in Tamil Nadu have been studied in greater detail by Sidhu (1963). Blasco (1975), Krishnamurthy et al. (1978; 1981) and Muniyandi and Natarajan (1983). About 20 woody species of mangroves are known in this area. Discontinuous mangrove formations have been observed in Cauvery delta, Pennar delta and further south in Tuticorin and Gulf of Mannar islands (Stoddart and Fosberg, 1972). The Muthupet swamp has been surveyed in detail by Azariah et al. (1990).

On the west coast, the mangrove formation of Kutch, Saurastra and Gulf of Khambat were surveyed by Sidhu (1963), Kulkarni (1957), Blasco (1975), and Untawale (1980). The mangroves of this region belong to the open scrubby type and they are most degraded. The mangrove foliage forms the principal source of fodder to about 2500 camels. The local inhabitants heavily depend upon mangrove thickets for fire wood and charcoal. Mangrove vegetaton has been reported to remain relatively undistributed in the Pirotan island and creeks.

In Maharashtra, the mangrove formations in Thana creek and Elephanta island were studied by Navalkar (1956) and Blasco (1975). The species composition and distribution of mangroves along Ratnagiri coast has been given by Joshi and Bhosale (1982).

The mangroves of Goa, especially those of Mandovi and Zuari estuaries have been elaborately studied by Untawale et al(1980; and 1982). The mangrove vegetation is reported to consist of about 20 species and include rare species such as Sonneratia caseolaris and Kandelia candel (K. rheedii). Untawale (1980) has reported the occurrrence of mangroves in Coondapur, Malpe and Karwar extending to an area of about 60 sq. km.

Specific aspects of research on Chemistry, physiology and biology of mangrove vegetation of India have been carried out from different schools of scientists in recent years. The chemical composition of certain species of mangroves were worked by Joshi (1975); Joshi and Bhosale (1982) on the Ratnagiri mangroves and by Untawale et al. (1980) for the Goa and Maharashtra mangroves. Joshi (1975) observed more values of Na, Cl, Phosphates and Carbohydrates in the leaves of A. marina than A. officinalis. Both species were observed to excrete salt. Untawale et al. (1980) reported that elements such as copperr, nickel, cobalt and lead showed no seasonal variation in the leaves of seven species of mangroves of Goa wherreas the concentrations of iron and manganese showed higher values during June to September.

The pathways of photosynthesis operative in most mangroves was observrved as C4 by Bhosale (1981) based on enzymatic studies conducted on the leaves.

The effect of pollution by petroleum products on the growth of seedlings of Avicennia officinalis and Rhizophora mucronata were investigated by Jagtap and Untawale (1980), and they reported that oil spillage may cause leaf and root damage, growth retardation and even death to seedlings.

The mangrove plankton flora at Pichavaram were studied by Sundara Raj (1978), Santhanam (1976), Kannan (1980) and Subramaniam (1981). About 40 species of phytoplankton were found to occur and some werre observed to cause blooms during summer..

The benthic nematode fauna in coastal waters have been studied by Damodaran (1972, 1973) in Kerala coast and by Ayyakkannu (1973) in Vellar estuary. In the Vellar estuary nematodes formed about 50-70% of total meio benthic animals and their number were high during summer compared to winter months.

Among the various faunal communities associated with mangroves, The juvenile populations of prawns and fishes have been studied in some detail by Palaniappan et al. (1981); Sambasivan et al. (1981) and Krishna Murthy et al. (1982). The distribution of finfish eggs, larvae and juveniles were studied by Krishnamurthy and Prince Jayaseelan (1981). They reported that disproportionate relationship between number of fish species represented by their eggs (10), larval stages (20) and juvenile stages (80) could be related to the breeding habits of the phyletic stock. They have also highlighted the loss encountered in the mangrove ecosystem on account of the traditional fisheries for juveniles.

The state of art and prospects of aquaculture in mangrove areas in India were reviewed by Parulekar (1985). According to him 45,000 ha of coastal mangrove swamps have been utilised for traditional farming methods such as bheris in West Bengal, Chemmeenkettu in Kerala, Gazani in Karnataka, Khazan in Goa and Khar lands in Maharashtra.

In the Chemmeenkettu fields of Kerala the production of shrimp and paddy during alternating seasons was estimated as 865 kg/ha and 500-1200 kg/ha respectively per season.

In experimental fish farms developed by reclamation of mangrove areas in Kakinada, Dwivedi and Reddi (1977) reported that prawn and fish production varied from 1390-2220 kg/ha. Prabhu and Matondkar (1978) while working on the culture of mullets and pearlspot in a fish farm surrounded by mangroves observed a net increase in fish biomass of $803.34 \times 10^3$ g C during the culture period and a high rate of return on investment.

Silas (1987) outlined the significance of mangrove ecosystem in the recruitment of fry and larvae of finfishes and crustaceans along the east coast of India particularly in the Sunderbans. He also drew attention to the mangrove dependent capture fisheries and captive fisheries. With regard to brackishwater aquaculture he cautions that natural resources of fish and prawn seeds have limitations in quantity and seasons of availability and suggests that future thrust in aquaculture should lay emphasis on hatchery production of seeds of cultivable species. This would also enhance the recruitment of juveniles of fishes and prawns to the mangrove dependent coastal fisheries. The formulation of an integrated coastal zone management policy for regulating all development activities in mangrove areas has been stressed.

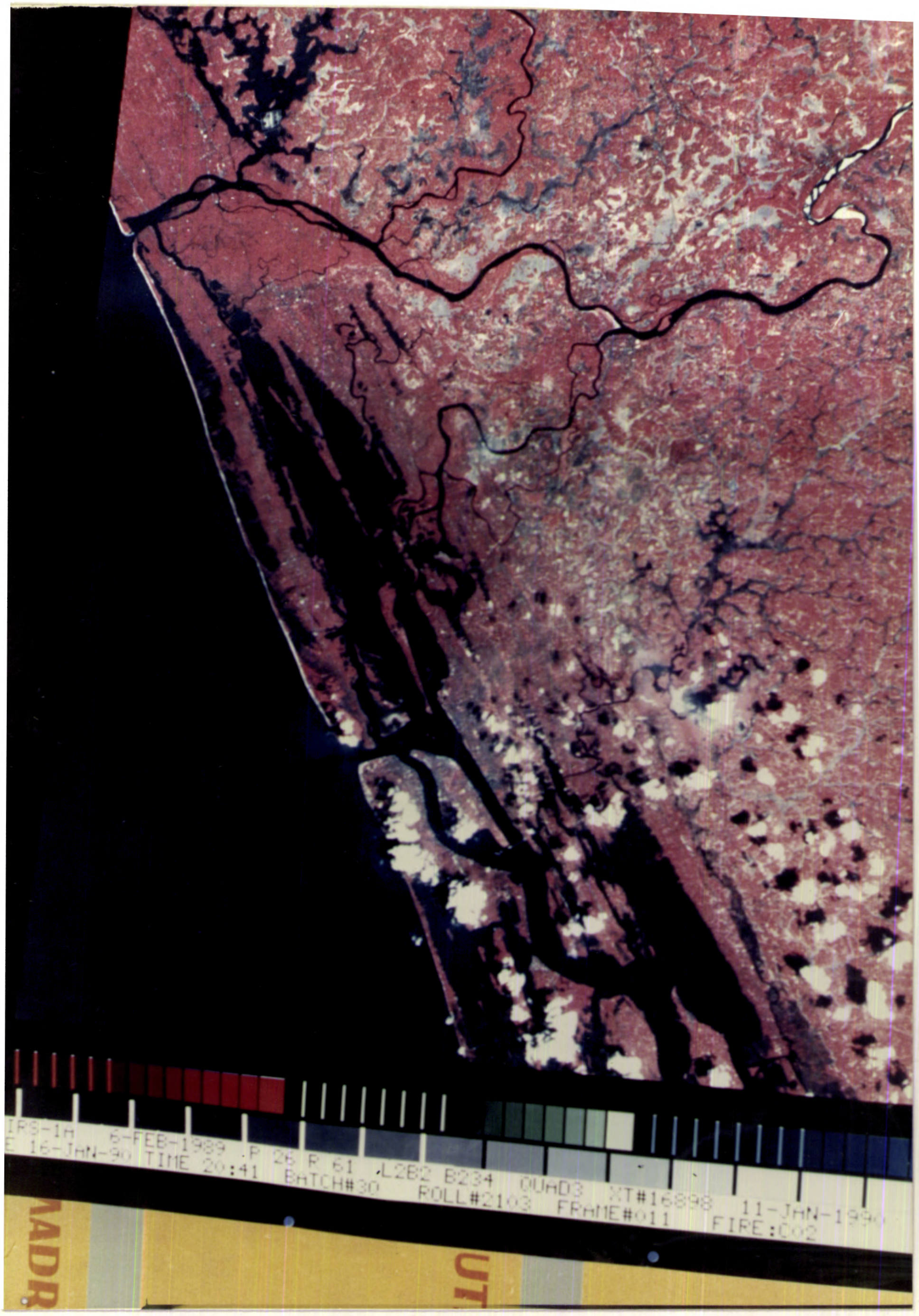
# 2. MATERIAL AND METHODS

TOPOGRAPHY AND ENVIRONMENT OF THE STUDY AREA

In the present study, mangrove communities occurring in Cochin backwaters and the Vembanad lake system have been covered. This vast estuarine system is one of the largest in the chain of backwaters in the Kerala State. This extends from Azhicode in the north to Alleppey in the south and is approximately situated between latitudes 9° 28'and 10°10'N and longitudes 76°13 and 76°31 E. The backwaters of the State are inter connected by a net work of canals. The State of Kerala itself is a narrow stretch of land sandwiched between the Arabian Sea on the west and the hills and high ranges of the western ghats on the eastern border. The coastline of Kerala is about 560 km comprising of raised beaches, sand bars, low lying marshes cultivated fields and coconut plantations interspersed with estuaries or lagoons. The Vembanad lake seems to have attained its present configuration in the 4th century A.D. according to historians. A catostrophic deluge which took place in 1341 A.D. gave rise to parts of the Alleppey and Ernakulam districts including a number of islands thus separating a distinct water body from the sea with connecting channels at Thottapalli, Andhakara Azhi and Cochin. It is at this period the river Periyar which was emptying at Cranganore (Kodungallur) took a diversion through Varapuzha and opened in the Cochin channel, giving rise to a number of islands lying scattered in the backwaters by deposition of alluvium in its course. This transformation of an originally marine environment into an estuarine system is evidenced by the occurrence of large quantities of marine shells deposited in the Vembanad region. Currently the freshwater discharge from major rivers such as Periyar,

Plate 1.

Photograph of a Satellite Image showing the Cochin estuarine system, the study area.


IRS-1A 6-FEB-1989 P 26 R 61 L2B2 B234 QUAD3 XT#16898 11-JAN-1990
E 16-JAN-90 TIME 20:41 BATCH#30 ROLL#2103 FRAME#011 FIRE:C02

Chalakkudi, Pamba, Achankovil, Manimala, Meenachil and Moovattupuzha make the backwaters typically estuarine in character (Gopalan et al., 1987).

The development of Cochin harbour (9°58'N and 76°14'E) has given all the importance to the estuary. The Cochin bar mouth was cut open in 1929 to a depth of about 10 m to allow ships of 30' draft to enter the harbour. About 780 acres of land (364 ha) was then reclaimed from the backwaters to create the port area named as Willingdon island. The harbour entance between Fort Cochin and Vypeen has a width of 450 m and in the middle it has been deepened further (15 m). This channel is responsible for the tidal rhythms that maintains the estuarine quality of the Vembanad lake.

The Vembanad lake and connected backwater system exert considerable influence on the socio-economics of the surrounding areas as the living resources available in the lake play an important role for the people living on its shore. The most important variable which controls the distribution, survival and growth of plants and animals in the ecosystem is salinity The wide spectrum of divergence in salinity from almost freshwater to seawater enables the sustenance of a variety of aquatic life both plant and animal, in the lake.

The Vembanad lake and adjacent backwaters are more influenced by the monsoons which bring about pronounced seasonal variations in salinity and other environmental parameters that may affect the vegetation and aquatic primary and secondary productions. Changes in the environmental parameters and production rates are also caused by the tidal influx, nutrients distribution, incident solar radiation and other factors.

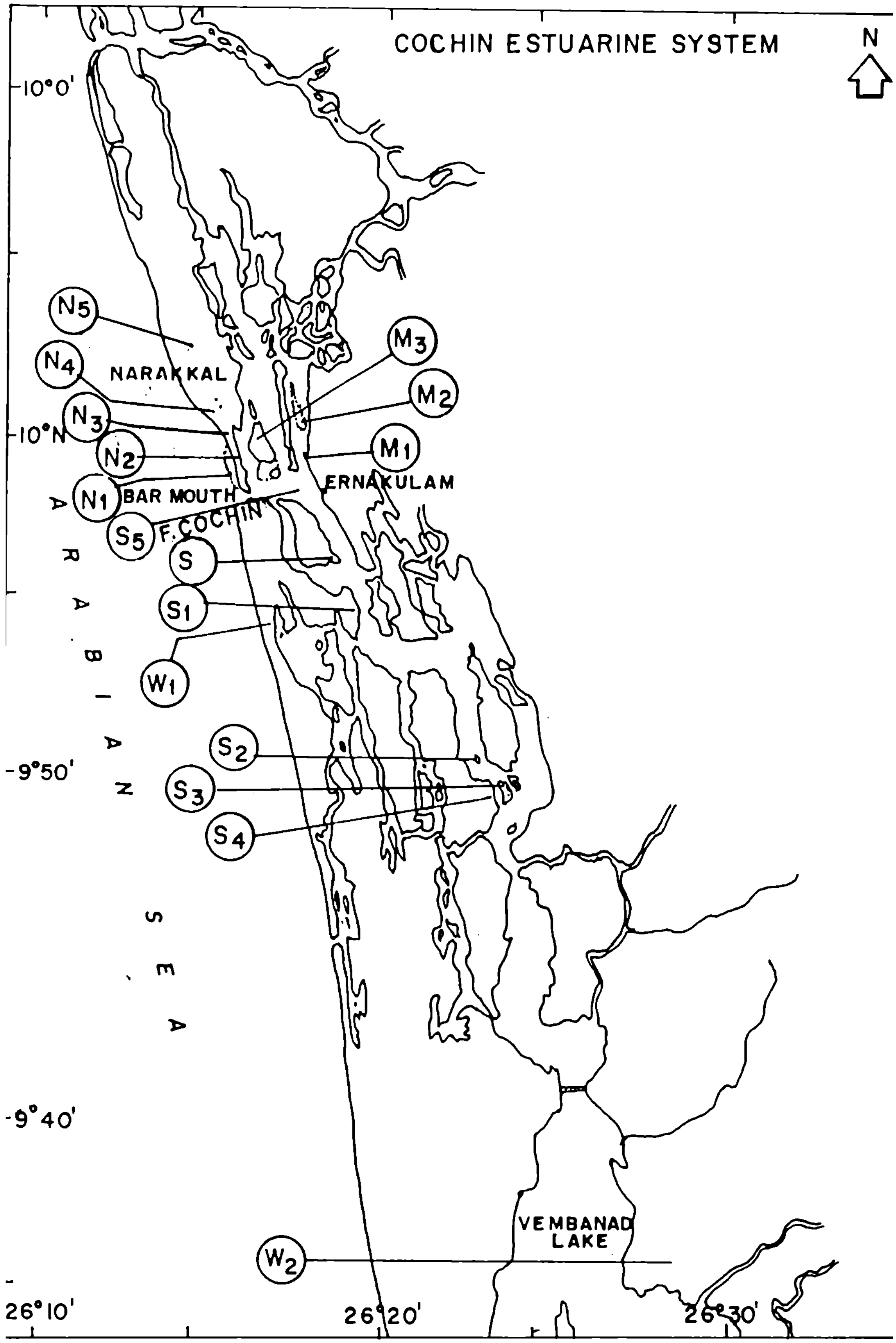



**Fig. 3.** Map showing the mangrove locations in the study area.

## BRIEF DESCRIPTION OF MANGROVE LOCATIONS

Different localities in the estuarine system were surveyed for the occurrence of mangrove vegetation, their extent, species composition, zonation and other ecological parameters. These locations are indicated in Fig. 3.

The location labelled 'S' is at the southern tip of the Willingdon island where mangrove vegetation is emerging due to fresh colonisation on a mud flat that has formed as a result of a reclamation work undertaken by the Port authority.

Location S-1 is a shallow bay in the estuary situated at a place called Pambaimoola, about 5 km south of Cochin harbour. The extent of mangrove area is less than 0.5 ha.

Locations S-2 to S-4 indicate small bays and islets in the vicinity of Perumbalam island situated about 12 km south of the harbour. The total extent of mangroves in these locations is about 5.0 ha.

Location S-5 refers to four small reclaimed islets witthin the Cochin harbour where mangrove regeneration and recolanisation is in progress.

Location M-1 is a mangrove swamp adjoining tthe Ernakulam Railway goods shed where a shallow tidal pond is surrounded by dense mangrove vegetation which has remained well preserved. The swamp has been declared as a protected area by the State authorities and named as 'Mangalvanam' by the Cochin Corporation. The extent of the swamp is 3.4 ha and this area serves as a sanctuary for aquatic birds.

Location M-2 is a mangrove area confined to the southern tip of Thanthoni island which is opposite the Bolgatty island.

Location M-3 refers to mangrove vegetation in Vallarpadom island occurring in the vicinity of prawn culture fields and in reclaimed areas on the southern side. The total extent of the mangrove habitats is about 10.0 ha

Location N-1 indicates the recent mangrove formation in the sea accreted area north of Cochin bar mouth and extending further north towards to Puduveyppu. The area colonised by mangrove vegetation is about 300 ha.

Location N-2 indicates the sea accreted areas of Puduveyppu about 3 km north of Vypeen on the western side of the Vypeen-Munambam road. This accetion is reported to have taken place after the Cochin bar mouth was opened in 1929. The sea shore is now 1.5 km west of the Munambam road. In the intervening area there is a resurgence of mangrove vegetation in addition to old stands that are surviving and propagating along the creeks and canals. The total area occupied by mangroves is about 20.0 ha.

Location N-3 and N-4 refer to the mangrove formations north of Puduveyppu at Malipuram and Valappu. The number of house holds and human population increase in the villages north of Puduveyppu and hence mangrove areas are disturbed.

Location N-5 is Narakkal where the population exceeds 3000 per sq.km and the area has been converted for agriculture, coconut plantation and prawn culture. The mangroves occurring here are under much stress.

Location W-1 indicates the coastal village of Kannamali about 8 km south of Fort Cochin where mangroves occur on the borders of tidal anals and derelict ponds. The total extent is about 5.0 ha.

Location W-2 indicates Kumarakom, a protected mangrove area near Kottayam. Here the mangrove trees have remained undisturbed and they exhibit luxuriance and species richness.

# MATERIAL AND METHODS

The present study is based on data collected during systematic surveys of different mangrove localities in the Cochin Estuarine System. Brief details of these locations have been given in the earlier chapter. The Data collected covered various aspects such as the status and extent of mangrove formations in the estuarine system, areas of regeneration of mangroves, areas of resurgence and fresh colonisation in reclaimed and sea accreted areas, areas which are left undisturbed and protected, species composition, distribution and zonation; climatic and edaphic factors, hydrography of mangrove waters, productivity of the ecosystem and the dependent fauna.

Aspects such as mangrove community structure, soil characteristics, hydrography and primary production were studied in selected locations which are indicated at the beginning of respective chapters.

The data and information were collected during different time frames, and a comprehensive study is presented here based on average values obtained from a number of observations for elucidating the ecology and dynamism of the mangroves of this region.

Standard methods as recommended by UNESCO (1984) for the study of mangrove ecosystem have been followed as far as possible.

Plant specimens

The plant specimens were collected during different seasons for studying their morphological characters and detailed notes and sketches were made. Herbarium material was prepared according to standard procedure (Unesco, 1984). Specimens were identified with the help of available literature and reference collections kept in different institutions.

Soil/Sediments

Soil samples were collected at 3 randomly selected plots inside the mangrove sites, to a depth of 15 cm. Physical characters such as colour and texture were noticed in the field. The samples were put into plastic bags and closed air tight with rubber bands and brought to the laboratory for processing and analysis.

Textural composition and chemical properties of soil such as pH, conductivity, cat-ion exchange capacity, exchangeable cat-ions and available nutrients were determined by following standard procedures as described by Jackson (1973), Piper (1966) and Walkley (1947).

Tidal fluctuations

Tidal fluctuations in selected mangrove areas were observed with reference to the Indian tide table and reference points marked at the sites with painted wooden reapers.

## Climatic factors

Data on atmospheric temperature, humidity, rainfall in the Cochin area was collected from the Cochin Port Trust as well as from the daily weather reports of India Meteorological Department.

## Hydrology of mangrove waters

Temperature of water samples was recorded on the spot using a 0-50°C mercury thermometer.

Salinity was estimated by Mohr-Knudsen method and Dissolved Oxygen content by modified Winkler's technique after fixing the samples at the collection spot with Winkler's A and B solutions.

pH of water samples was estimated using a digital pH Meter. Nutrient samples were collected in polythene bottles at the sampling sites and transferred to the laboratory in ice-boxes.

Nitrite-nitrogen was estimated by Bendscheider and Robinson method and the absorbance was measured at 540 nm using a 'Pye Unicam' Spectrophotometer. The Nitrite-nitrogen was estimated according to Morris and Riley method and absorbance measured at 540 nm.

Phosphate estimation was carried out by Murphy and Riley method and extinction was measured at 885 nm. Silicate was estimated by Mullin and Riley method and extinction measured at 810 nm.

All the above methods are described in detail by Strickland and Parson (1968) and Parson *et al.* (1984).

Phytoplankton productivity

Primary production in the mangrove waters has estimated by $C^{14}$ techniques.

Chlorophyll content was estimated as per methods described by Parson *et al.* (1984).

Mangrove community structure

Modern research work on mangrove ecosystems place emphasis on understanding structural variations in mangrove forests. The basic requirements for quantitatively determining physiognamic structure of mangrove communities have been reviewed by Cintron and Novelli (1984). Based on the methods recommended by them the following sampling procedure was adopted.

Mangrove localities in the study area, N-1, N-2, M-1 and M-3 were selected for study of community structure. In each locality random plots of size 100 m x 100 m was fixed. In each plot smaller quadrats of 10 m x 10 m were selected at random as sampling units.

In each sampling unit, all stems having diameter greater than 2.5 cm were counted species wise. For seedlings and shrubby vegetation, smaller quadrats of 1 x 1 m size was used to work out the percentage of density. Tree diameter at the sampling sites were measured at breast height (1.3 m above ground) using a vernier calipers for thin stands and by measuring the circumference of larger trees with a tape.

Where the stems forked below breast height (most Avicennia stands) each of the branches were measured. Where the stems forked above breast height, diameter was taken below the fork. In the case of Rhizophora stem diameter was measured above the prop roots.

Basal area

For each stem, the diameter measured in cms was utilised for estimating the basal area in $m^2$ by using the conversion factor, $0.00007854\ (dbh)^2$.

$$\text{Mean basal area per tree} = \frac{\text{Basal area per ha.}}{\text{No.of trees per ha}}$$

Tree height:

Tree height was measured by using a graduated pole for smaller trees and a clinometer for tall trees.

Based on the data collected from sampling plots the following parameters were calculated.

a) $\text{Relative density} = \frac{\text{No.of individuals of the species}}{\text{Total number of Individuals}}$

b) $\text{Relative dominance} = \frac{\text{Basal area of a species}}{\text{Total basal area of all species}}$

c) $\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum frequency of all species}}$

Importance value = Sum of above values a + b + c

Shannon index for species diversity

$$H = - \Sigma \, Pi \log Pi \text{ where}$$

$$Pi = \frac{\text{Importance value of a species}}{\text{Total importance value of all species.}}$$

Complexity index

Complexity index of Holdridge *et al.* (1971) was calculated using the formula,

$$\frac{(S) \quad (d) \quad (b) \quad (h)}{10^3}$$

Where S = the number of species per 0.1 ha plot

b = basal area

d = density

h = height

# 3. MANGROVE FLORA

## SPECIES COMPOSITION, ZONATION AND DISTRIBUTION

Blasco (1975) in his report on Indian mangroves observed that the mangrove formations in Kerala represented only a feeble fraction of the total extent of mangroves in India (less than 0.5%) and as a result they had not evoked much interest among botanists and foresters. In fact, Kerala was not included in the list of States while computing the extent of mangroves in India by Sidhu (1963) and Blasco (1975).

However, Blasco did make a survey of Kerala's backwaters from Quilon to Alleppey and Cochin and he gained the impression that there are no more mangrove vegetation except clumps of Acanthus ilicifolius and bushes of Cerbera manghas and Acrostichum aureum.

At the beginning of this century Bordillon (1908) reported the occurrence of Bruguiera gymnorrhiza and two species of Rhizophora as being common at Quilon. Notwithstanding the patchy nature of mangrove tract in this region, the need for their survey was stressed by Silas, (1987) from the fisheries point of view.

In the present study, 16 locations having varying degrees of mangrove formation were investigated. Brief description about their topography have already been given. Aspects such as, species composition, zonation and locationwise species distrbution are presented as follows:-

### Location S.

The mangrove formation at the southern tip of Willingdon island is an emerging one facilitated by the silting of the backwaters as a result of a reclamation work of the port that has been in progress. About 10 years ago there was only a small patch Avicennia officinalis in this area. The formation of a mudflat of about 100 m length has enabled this species to colonise rapidly and advance towards the water front. The early colonisers of this species have grown to heights ranging from 5- 6 m and the young stands are 1-2 m. Seedlings of this species of getting continuously established in the prograding formation. On the opposite side where the backwater has been bunded for the formation of a road bridge, strubs of Acanthus ilicifolius have colonised. On the eastern side of the above formation young stands of Rhizophora mucronata are growing. As the vegetation is informative stages zonation is ill defined at present.

Location S-1. (Pambaimoola)

The shallow bay here is occupied mostly by the shrub, A. ilicifolius and towards the water front there are discontinuous patches of A. officinalis and R. mucronata. At higher elevations Thespesia populnea and coconut trees dominate. Zonation is thus feeble.

Location S-2. (Islet opposite Perumbalam)

In this uninhabited islet, the slightly elevated central portion is occupied by A. officinalis and one or two stands of Cerbera manghas The shrub Clerodendrum inerme and isolated stands of Excoecaria agallocha and Aegiceras corniculatum are intermingling. The water front is occupied by discontinuous stands of Rhizophora mucronata. The islet is therefore a mixed zone of mangroves and structurally ill developed mostly due to poaching of wood for fuel.

Location S-3. (Island, south of Perumbalam)

As this island has been converted for paddy cultivation and the bunds are planted with coconuts, only the fringes are colonised by A. ilicifolius, C. inerme, A. corniculatum and R. mucronata. A few sandy patches in the border of the island is invaded by Ipomoea pescaprae and tufts of the fern Acrostichum aureum.

Location S-4. (East of Turavoor)

As a portion of the coastal stretch of main land the area is inhabited and converted vastly for coconut farms. In the creeks and ponds that intervene are bordered with medium sized A. officinalis, R. mucronata, Bruguiera cylindrica, A. corniculatum, E. agallocha and A. ilicifolius. On the landward side Clerodendrum inerme, Acrostichum aureum Calophyllum inophyllum, Ipomoea pes-caprae and Eriocolon sp. do occur.

Location S-5. (Small islands adjacent to oil tanker berth of Cochin harbour)

There are four small islets which have emerged in the process of dredging of harbour channels and reclamation some 40 years ago. Prior to 1980 these islands were surveyed by the candidate and the vegetation comprised of well developed stands of R. mucronata, A. officinalis intermingled with E. agallocha, C. inerme, A. ilicifolius and Aegiceras corniculatum on the borders and along the tidal creeks of the islets. The Central portion of some the islets had terrestrial trees such as Enterolobium saman and creepers such as Ipomoea pes-caprae, I. palmata and marsh grass, Panicum psilopodium. At present these vegetation look degraded and stunted as they were cut down in the early eighties for the construction of a super tanker berth. A officinalis and A. ilicifolius, E. agallocha are recolonising along with a few saplings of R. mucronata

Location M-1 (Thoosath, now "Mangalvanam")

As this mangrove swamp has remained undisturbed the dense tree forms of Avicennia officinalis dominate the forest with a few isolated stands of Rhizophora mucronata along a narrow creek. The edge of the water is occupied by dense patches of Acanthus ilicifolius at a few places. On the land ward fringe there are some tall trees such as Enterolobium saman, Cassia fistula, Artocarpus hirsuta. The zonation is distinct here ie. A. ilicifolius at the water front, A. officinalis in the slope going up and terrestrial species in the landward boundary (Fig. 4).

Location M-2. (Thanthoni island)

The southern tip of this island has two rows of A. officinalis trees behind which a tidal pond of 0.5 ha is surrounded by A. ilicifolius. The households are surrounded by Thespesia populnea and a few stands of R. mucronata and B. cylindrica. Along the rest of the island, central portions are utilised for paddy culture, prawn culture and coconut farms.

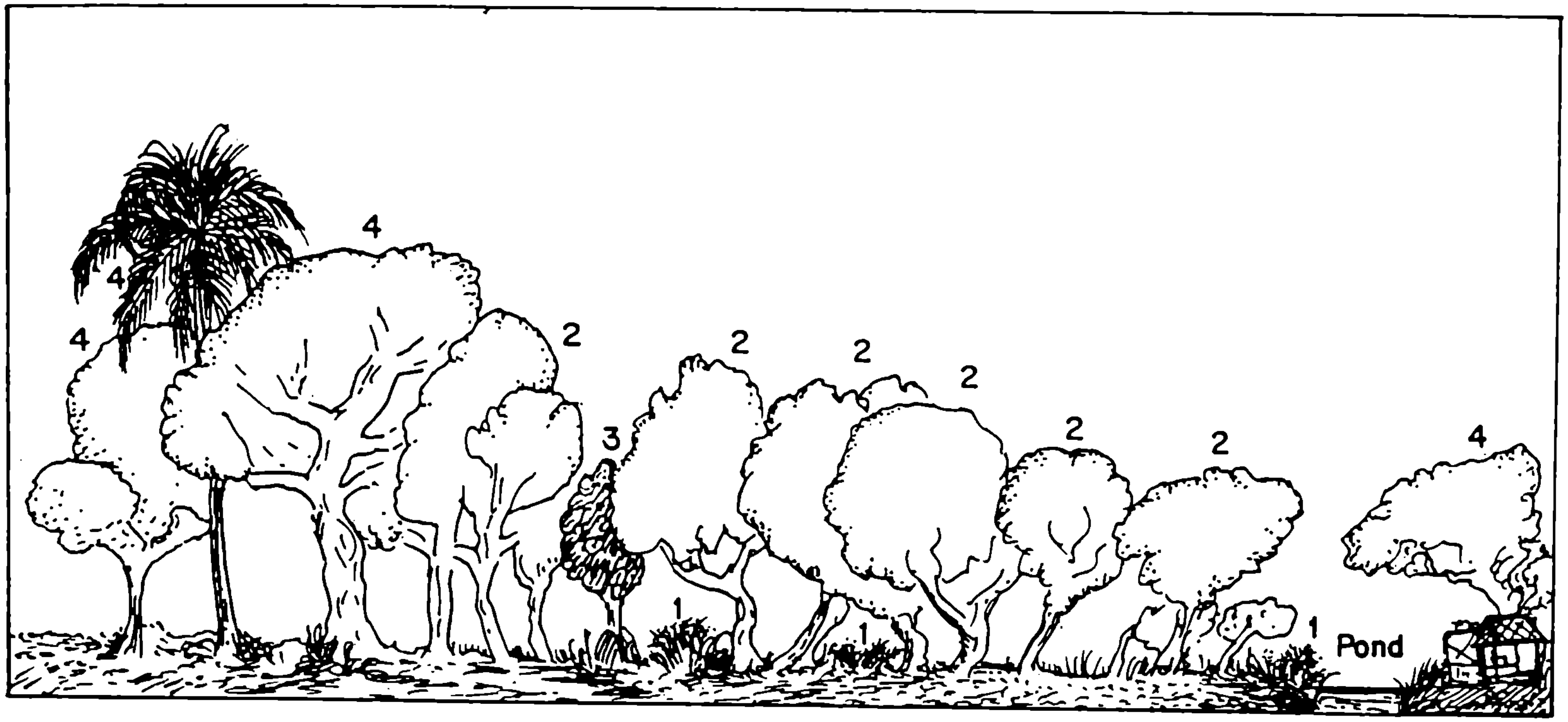



**Fig. 4.** Diagramatic profile of vegetation at Location M-1 (Not to scale)

1. **Acanthus ilicifolius**
2. **Avicennia officinalis**
3. **Rhizophora mucronata**
4. **Other terrestrial species**

Plate 2.

a) Top: View of Location M-1 ("Mangalvanam") dominated by stands Avicennia officinalis.

b) Bottom: View of recent formation of A. officinalis in sea accreted area at Location N-1 (Near Vypeen).

Location M-3 (Vallarpadam island)

Although this island is inhabited and a greater portion of it has been converted into aquaculture ponds, paddy fields and coconut farms, mangrove vegetation has been left intact in certain areas adjacent to the culture ponds. Close to the Vallarpadam boat jetty there are over 100 stands of R. mucronata some of them reaching heights over 10 m on the borders of tidal inlet canals and prawn culture ponds. An under-storey of A. officinalis and A. ilicifolius invariably occur. The house holds are bordered with rows of Thespesia populnea.

On the southern side of the island which has been reclaimed, bushes of Avicennia officinalis and dense population of A. ilicifolius have developed. In the portion which was originally occupied by another island known as Ramanthuruth there are a few relic stands of Sonneratia caseolaris and Bruguiera gymnorrhiza.

On the western side, some of the aquaculture sites are bordered with old stands of R. mucronata. B. cylindrica and A. officinalis intermingling with Thespesia populnea and Clerodendrum inerme. A. ilicifolius is colonising in discontinuous patches. It is note worthy that a few relic stands of Rhizophora apiculata are also left intact.

Location N-1. (Vypeen)

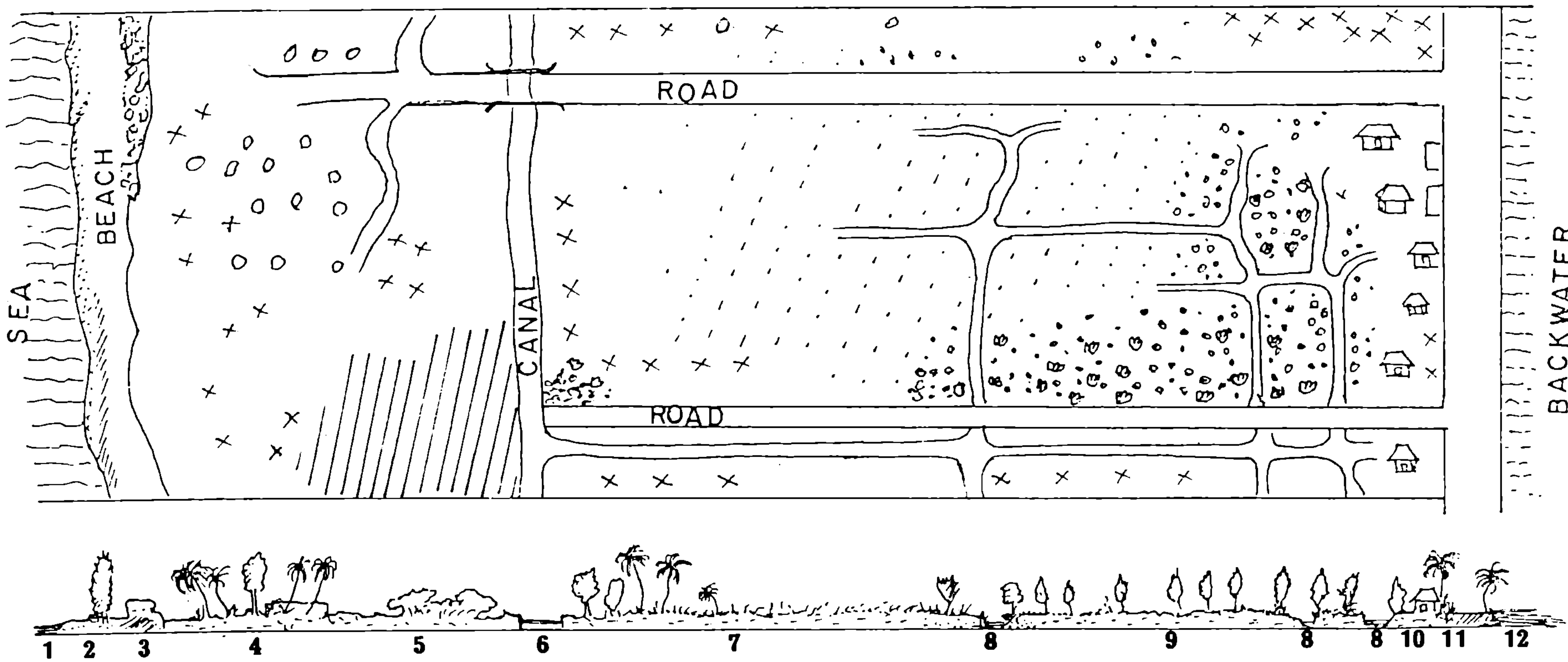
A vast stretch of sea accreted mudflat has been formed in recent years north of the Cochin bar mouth and parallel to the Vypeen village for about 3 km north, joining Puduveyppu. This entire stretch has been dominated by young stands of A. officinalis with occasional patches of E. agallocha, C. inerme and A. ilicifolius. The elevated portions are invaded by strand vegetation such as Cyperus spp., Ipomoea spp and grass varieties.

Loation N-2. (Puduveyppu)

This is also a sea accreted area. Close to the Vypeen-Munamban road on the western side there are remnants of the original sea wall which separated the land from the sea. As accretion proceeded during the past 30-40 years, the shore line has shifted by about 1.5 km from the present road. The sea ward zone in the proximity of the Brackishwater fish farm of the KAU is planted with rows of Casuarina and the sandy tracts are colonised by strand vegetation. A tidal canal runs from the north and joins the Cochin harbour entrance channel separating the Avicennia zone at N-1. (Fig. 5).

East of this canal, there are extensive colonies of A. ilicifolius with isolated patches of E. agallocha, and A. officinalis. The area close to the Munambam road have extensive 5-10 m tall stands of R. mucronata, B. cylindrica and B. gymnorrhiza with an understorey of Clerodendrum inerme, Sesuvium portulacastrum and Suaeda maritima in certain locations. A few stands of Bruguiera sexangula have also been observed. Associated trees are those of Thespesia populnea, and Terminalia catappa.

**Fig. 5.** Diagram to show distribution and zonation of vegetation at Location N-2 (Not to scale)




1. Sea and beach 2. Casuarina plantation 3. Granite sea wall 4. Mixed terrestrial vegetation and Brackishwater aquaculture farms of KAU. 5. Avicennia zone 6. Canal 7. Zone of Acanthus ilicifolius 8. Tidal creeks 9. Mixed zone of Rhizophora,-Bruguiera 10. Residential area 11. Vypeen-Munambam Road 12. Backwater xx. Coconut plantation.

Location N-3 (Malippuram)

Along the road leading to the light house there are a few swampy areas connected to the backwater canals. Here the pattern of vegetation from the edge of water towards the landward fringe is as follows: A. ilicifolius, C. inerme, B. cylindrica, E. agallocha, old stands of A. officinalis, Cerbera odallam, Thespesia populnea, Terminalia catappa and coconut trees.

Location N-4. (Valappu)

In the vicinity of the fish farm belonging to the local Harijan Welfare Society, the tidal creeks are bordered with R mucronata, A. officinalis, B. cylindrica, E. agallocha, A. ilicifolius and Clerodendrum inerme. The surrounding areas are densely covered by stands of Thespesia populnea, Areca catetchu, Hibiscus tiliaceous and coconut groves.

Location N-5 (Narakkal)

In the vicinity of CIBA and CMFRI establishments some of the tidal creeks and ponds are bordered with occasional stands of R. mucronata, A. officinalis. B. cylindrica and E. agallocha with an understorey of A. ilicifolius and C. inerme. The side of the narrow canals irrigating the coconut groves are invariably colonised by stumpy forms of E. agallocha and Acrostichum aureum. The residential areas are surrounded by terrestrial vegetation such as Thespesia populnea, Artocarpus integrifolia and Areca catetchu. (Fig.6.)

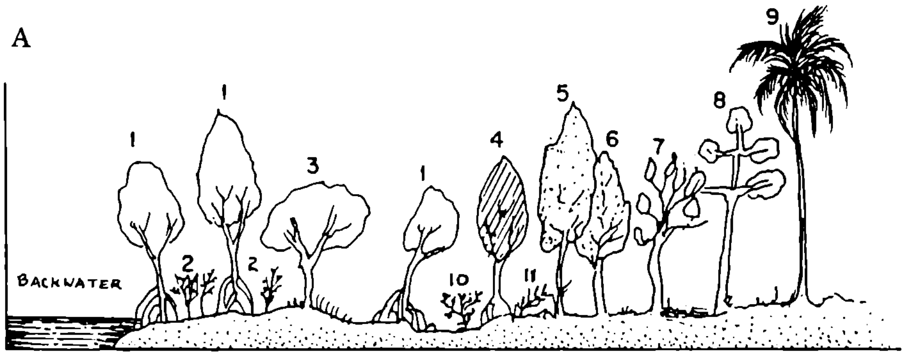
A. Vegetation at Location W-1 (Kannamali)

1. Rhizophora mucronata
2. Acanthus ilicifolius
3. Avicennia officinalis
4. Rhizophora apiculata
5. Bruguiera cylindrica
6. B. gymnorrhiza
7. Cerbera odallam
8. Thespesia populnea
9. Cocos nucifera
10. Excoecaria agallocha
11. Acrostichum aureum

B. Vegetation at Location N-5 (Narakkal)

1. Acanthus ilicifolius
2. Rhizophora mucronata
3. Avicennia officinalis
4. Thespesia populnea
5. Bruguiera cylindrica
6. Clerodendrum inerme
7. Acrostichum aureum
8. Excoecaria agallocha
9. Cocos nucifera
10. Artocarpus integrifolia

A




B

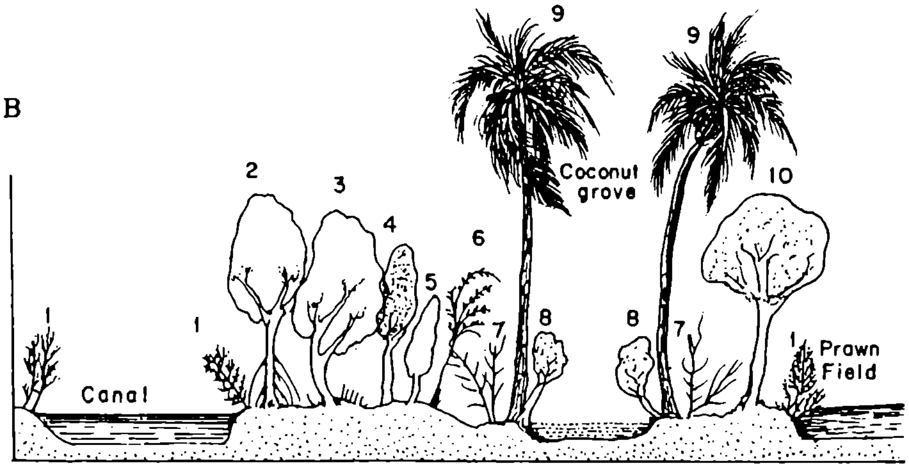



**Fig. 6.** Diagram of transects to show distribution of vegetation (Not to scale)

Plate 3.

Stands of Rhizophora mucronata at Location N-2.

Location W-1. (Kannamali)

The mangrove area is close to the sea shore but separated by the coastal road. The canals and some of the wastewater ponds are bordered with R. mucronata and A. officinalis. Behind these stands, B. cylindrica, B. gymnorrhiza and R. apiculata occur in limited numbers. A ilicifolius, E. agallocha and Acrostichum aureum are common on the sides of the creeks passing through house holds and in the road side. Cerbera odallum, Clerodendrum inerme, Calophyllum inophyllum and Thespesia populnea are also common. ( Fig.6).

Location W-2 (Kumarakom)

Being a protected area and a bird sanctuary the area harbours some rare species of mangroves such as Heritiera littoralis, Sonneratia caseolaris and Kandelia candel which are uncommon around Cochin. The waterfront is bunded by a laterite wall and normal tidal inundation is restricted except through seepage. The immediate water front side is occupied by mixed stands of R. apiculata and Kandelia candel. B. gymnorrhiza, A. officinalis are closely behind. Towards the interior, Sonneratia caseolaris, Barringtonia racemosa, Thespesia populnea, Terminalia catappa, Calophyllum inophyllum are met with. The trees are over 10 m tall.

The location wise description of the species composition and their broad zonation pattern have been given in the foregoing paragraphs. A summary of species distribution in all the locations surveyed is given in Table 1 .

As could be seen from the table, Avicennia officinalis, Rhizophora mucronata, Acanthus ilicifolius have a high percentage of frequency of occurrence. Next in the order comes species such as Clerodendrum inerme, Excoecaria agallocha, Bruguiera cylindrica and Acrostichum aureum. Among the terrestrial species, Thepesia populnea dominates as the principal associate. In general coconut plantations are predominant on the landward fringe of most of the mangrove locations. In addition wherever people have settled, the mangrove dwellers, if we may call them so, have planted a number of terrestrial trees and shrubs. Also on the beach side strand vegetation is met with in patches. While an exhaustive survey of these vegetation is beyond the objective of the present study, an indicative list of such species is appended at the end.

As regards the number of species of mangroves and their close associates, the location N-2 and W-2 are rich in species. N-2 is a sea accreted area where the population density is sparce and the land area has not been leased out for conversion to other uses. As already stated, Kumarakam (location W-2) is a protected area.

The very recent mangrove formation in location N-1 near Vypeen is now densely occupied by stands of Avicennia officinalis and hence other species are limited.

At 'Mangalvanam' (location M-1) although the area has remained undisturbed, the number of species is very limited. In all other locations the number of species ranges from 3-10.

In the present study, three species of Bruguiera, viz., B. cylindrica, B. gymnorrhiza and B. sexangula have been recorded from location N-2, perhaps for the first time. Similarly the occurrence of Rhizophora apiculata and Sonneratia caseolaris at location M-3 was noticed for the first time. The ocurrence of residual Kandelia candel and Heritiera littoralis at Kumarakam is of considerable scientific interest.

It has also been observed that Aegiceras corniculatum and Avicennia marina are becoming rare in the study area.

Species such as Ceriops tagal, Lumnitzera racemosa, Rhizophora stylosa, Sonneratia apetala and Xylocarpus granatum common in the East Coast are conspicuous by their absence.

Zonation

Because of limited extent of mangrove areas in most locations, zonation was observed to be feeble and indistinct. The edge of the water is usually occupied by species such as, A. ilicifolius, A. officinalis and R. mucronata, behind which a mixed zone of 4-5 species occur.

In Vypeen - Pudveyppu area, a back water canal separates a distinct zone of A. officinalis lying parallel to the sea shore. On the eastern side of the canal, an extensive formation of A. ilicifolius occurs. Further towards the land ward side, there is a belt having mixed stands comprising of species of Bruguiera, Rhizophora and Avicennia along with other shrubby forms such as Excoecaria agallocha.(Fig.5.)

At 'Mangalvanam' the water front is occupied by a gregarious formation of A. ilicifolius in the form of a broken belt and this is followed by rows of A. officinalis with large terrestrial trees in the back ground. A few numbers of Rhizophora occur within the Avicennia zone. The above zonation patterns are depicted in Fig.

## Discussion

Blasco (1984), while reviewing the taxonomic considerations of mangrove species stated that generally the woody plants found in the mangroves of the world comprise of 53 species belonging to 23 genera and 16 families. Many herbaceous or semi woody halophytes are often found in mangroves as a result of habitat disturbance due to human interference. Most of them belong to the family Chenopodiaceae. In addition some grasses (e.g. Porteresia, Aeluropus and members of Cyperaceae, Aizoacea, Boraginaceae and Pteridophytes (Acrostichum aureum are often present in mangrove areas. Blasco (1975) included these species in the list of mangroves of India. Chapman (1984) also recommended their cognizance in the mangrove list. He admitted the difference of opinion regarding what could be included as a mangrove when one considers the landward edge of the swamp or the transition to freshwater conditions. Therefore in his list of distribution of phanerograms of mangrove regions he indicated 34 species as present in India.

Anon (1987) indicated 50 species belonging to 30 genera as principal mangrove species in India.

Recently Anon (1990), the M.S. Swaminathan Foundation have indicated that the Indian mangroves approximately comprise of 59 species belonging to 41 genera and 29 families. Of these 32 species are reported as belonging to the west coast.

They have pointed out that Sonneratia caseolaris is fast disappearing from the West coast and S. apetala is found only in Maharashtra coast. The species diversity is much greater along the East Coast and in the Andaman Nicobar islands, 34 and 46 respectively.

Table-1. Locationwise distribution of mangrove species.

| Species | Locations | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | S-1 | S-2 | S-3 | S-4 | S-5 | M-1 | M-2 | M-3 | N-1 | N-2 | N-3 | N-4 | N-5 | W-1 | W-2 |
| Acanthus ilicifolius | x | x | | x | x | x | x | x | x | x | x | x | x | x | x | |
| Aegiceras corniculatum | | | x | x | x | x | | | | | | | | | | |
| Avicennia officinalis | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | x |
| A. marina | | | | | | r | | r | | | | | | | | r |
| Bruguiera cylindrica | | | | | x | | | x | x | | x | x | x | x | x | |
| B. gymnorrhiza | | | | | | | | | x | | x | | | | x | x |
| B. sexangula | | | | | | | | | | | x | | | | | |
| Exocoecaria agallocha | | | x | | x | x | | | | x | x | x | x | x | x | |
| Kandelia candel | | | | | | | | | | | | | | | | x |
| Rhizophora apiculata | | | | | | | | | x | | | | | | x | x |
| R. mucronata | x | x | x | x | x | x | x | x | x | . | x | . | x | x | x | . |
| Sonneratia caseolaris | | | | | | | | | x | | | | | | | x |
| Acrostichum aureum | | | | x | x | | | | | | | | | x | x | |
| Sesuvium portulocastrum | | | | | | | | | | x | x | | | | | |
| Suaeda maritima | | | | | | | | | | x | x | | | | | |
| Clerodendrum inerme | | | x | x | x | x | x | | x | x | x | x | x | x | x | |

X = OCCURRENCE Y = RARE

# LIST OF MANGROVE ASSOCIATED VEGETATION

This list contains species which occur in the landward side of mangrove swamps as well as littoral species that occur near the seashore. In the densely populated areas such as Narakkal, Valappu, Malipuram, Fort Cochin, Kannamali and further south in the mangrove loations near Vaikom, Poothotta, and in Kumarakom many terrestrial species also find a place as associated vegetation. Some of these have been perhaps introduced by local inhabitants.

LIST

| Family | Species | Local name (Malayalam) |
|---|---|---|
| Anonaceae | Anona squamosa L. | Aatha chakka |
| | Cananga odorata Hf & T | Kaatu chempakam |
| | Polyalthia longifolia Benth | Arana |
| Caesalpiniaceae | Cassia fistula L. | Konna |
| | Caesalpinia pulcherima S.W. | Raja malli |
| Mimosaceae | Enterolobium saman (Benth) | Urakkamaram |
| Papillionaceae | Pongamia pinnata<br>Derris trifoliata | Ungu |
| Casuarinaceae | Casuarina equisetifolia Forst | Mooli |
| Moraceae | Artocarpus integrifolia L. | Pilavu |
| | A. hirsuta | Angeli |
| | A. incisa | Kadapilavu |
| | Ficus religiosa L. | Arasu, Arayal. |

| | | |
|---|---|---|
| Caricaceae | Carica pappaya L. | Pappali |
| Bombacaceae | Bombax malabaricum | Elavu |
| Malvaeae | Hibiscus tiliaceous L. | |
| | Thespesia populnea Cav | Poovarasu |
| Clausiaceae | Calophyllum inophyllum | Punna |
| Barringtoniaceae | Barringtonia racemosa (L) | Samudraksham |
| | Couroupita guianensis | Nagalinga |
| Combretaceae | Terminalia catappa L. | Thallithenga |
| Loranthaceae | Viscum orientale | |
| Simarubaceae | Samadera indica | Karingotta |
| Apocynaceae | Cerbera odallam Gaertn | Odallam |
| | Nerium odorum | Arali |
| Asclepiadaceae | Calatropis gigantea | Erukku |
| Rubiaceae | Ixora coccinia L. | Chethipoo |
| Verbenaceae | Lantana spp. | |
| | Vitex negundo | Karinochi |
| Cyperaceae | Cyperus javanicus | |
| Pandanaceae | Pandanus fascicularis | |
| Poaceae | Phragmites karka | |
| Convolvulaceae | Ipomoea pescaprae | |
| Pontederiaceae | Eichhornia crussipes | |
| Palmae | Areca catetchu L. | Adakka |
| | Cocos nucifera L. | Thengu |
| Graminae | Spinifex littoreus | |
| | Panicum psilopodium | |

# MORPHOLOGICAL DESCRIPTIONS OF MANGROVE FLORA OF STUDY AREA

These species described here have a wide distribution in the Indo-Pacific region. However, in different ecological niches, variations in morphological characters may be encountered. There will also be variability in the girth and height attained which may depend on zonation and other local edaphic conditions. The specific location from where single species or multispecies have been observed and studied are given.

## ACANTHACEAE

**Acanthus ilicifolius** Linnaeus (Plate 4a)

Acanthus doloarin Blanco

Dilvaria ilicifolia Juss.

A common halophytic shrub that spreads along the border of creeks, canals and ponds; grows to a height of about 1.5 to 2.0 m.

Stems: Green to brownish green, slightly hard but flexible, grows in clusters.

Leaves: Holly shaped, pinnatified, toothed with sharp spines, margin (rarely) entire, opposite.

Inflorescence: Terminal or pseudo axillary spikes.

Flowers: Bracts ovate, large spinescent with decussate bractioles; 4 partite calyx with larger outer lobes; a short corolla tube with obsolete upper lip; lower lip obovate and slightly trilobed, bluish-purple colour; stamens-4, didynamous, shorter than lower lip, filament curved, not protruding

Plate 4.

a) Top: *Acanthus ilicifolius*

A gregarious shrub found commonly in most of the mangrove habitats.

b) Bottom: *Avicennia officinalis*

A common woody species widely distributed.

beyond the anther; anther one celled, oblong; ovary - two celled with two ovules in each cell; style-slender, stigma-bifid.

Fruit: An ellipsoid capsule with 4 compressed seeds.

AVICENNIACEAE

**Avicennia marina** (Forsskal) Vier,

Sceura marina Forssk.

A. spherocarpa "Stapf ex Ridley"

A. officinalis Auct. ex. cuf. sensu matsum.

A. nitida sensu Blanco

Short stumpy shrubs to medium sized trees; bark smooth, grey; yellow indumentum on young twigs.

Leaves: Opposite, coriaceous, entire, oval, rounded/pointed apically; some times glaucous white beneath.

Inflorescence: Cymose with 4-16 flowers forming a head.

Flowers: Sessile, diameter - 4-5 mm bracteate, pleasant smelling Calyx-short, 4-5 sepals, polysepalous, green villous, Petals-4, gamopetalous, yellow stamens-4, epipetalous, filament short, anther reniform, style robust, stigma bifid, ovary with a medium ring of hairs, 4 pendulous ovules.

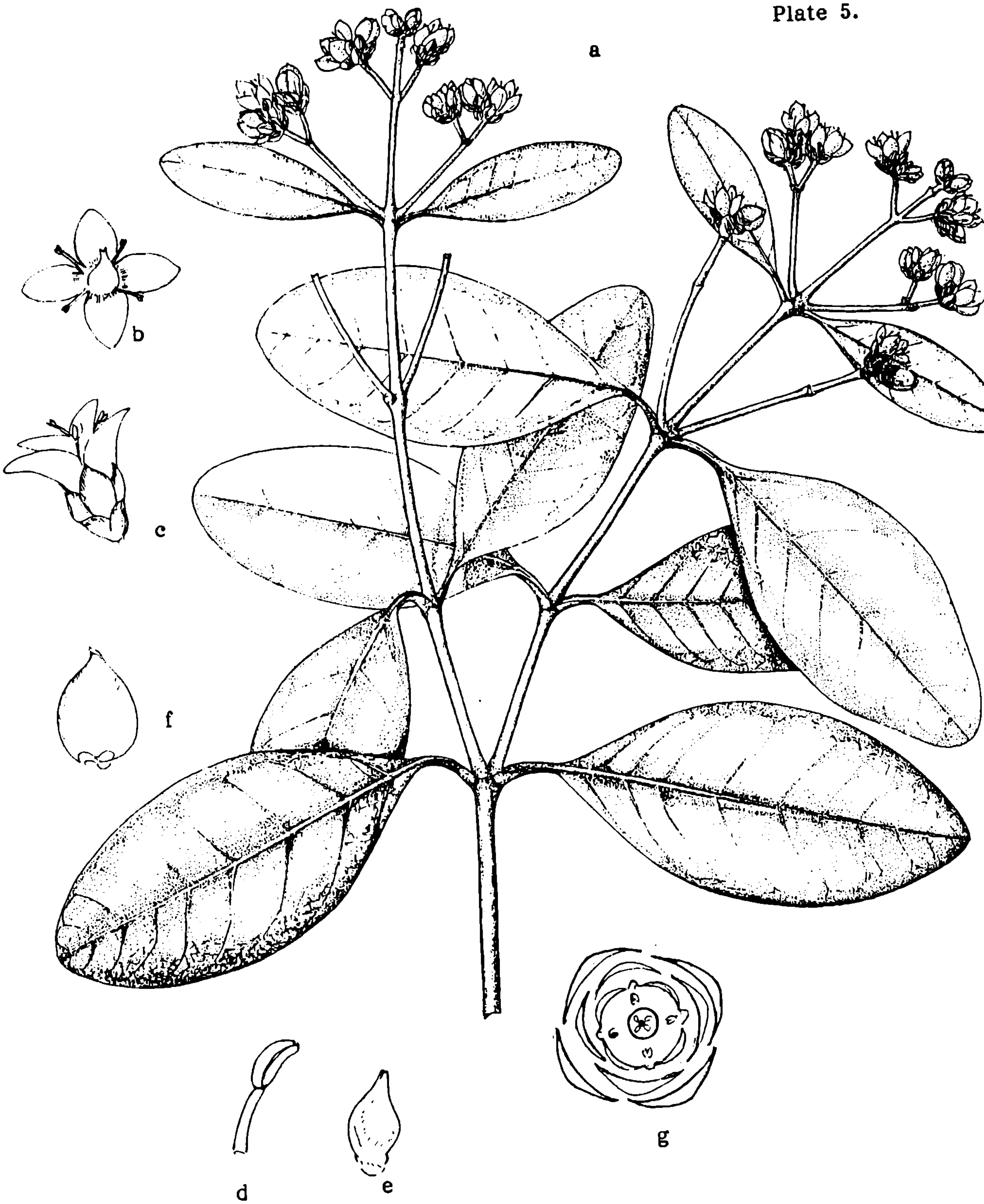
Fruit: Cordate, compressed capsule, dehice by two leathery coats; greyish-yellowish green when ripe.

Plate 5.

Morphological features of *Avicennia officinalis* Linneaus.

a) Flowering shoot (x1)
b) Individual flower, view from top (x3)
c) Individual flower, view from side (x 2.5)
d) Stamen (x5)
e) Ovary (x4)
f) Fruit (x 3/4)
g) Floral diagram

Plate 5.



**Avicennia officinalis** Linnaeus (Plate 4b, 5)

A. tomentosa Willd

A. obovata Griff.

Gregarious shrubs to trees reaching 8-10 m height, bark-dark grey.

Leaves: Ovate or broadly elliptic to obovate, apex rounded, glabrous shining above, minutely brownish beneath; size upto 10 cm long, 5 cm broad

Inflorescence: Heads of close cymes, some times forming terminal trichotomous panicles, branches short.

Flowers: Orange-yellow, diameter 10-12 mm; sessile, bracts with imbricate margin becoming black with age; Calyx short, 4-5 sepals; Corolla tube short; petals-4, united, adaxial lobe of corolla becomes broader, tips of petals unfold irregulary with age, beomes brownish or blackish, Stamens - 3-4 mm long, exserted, well developed filaments, longer than anthers, anthers spatulate; ovary densely hairy except at the tip of style; stigma lobes unequal.

Fruit: 2 - 2.5 cm long, russet brown when ripe, cordate capsule, larger than that of A. marina. Pericarp in the form of two leathery coats; hypocotyl of seedlings hairy.

RHIZOPHORACEAE

**Rhizophora apiculata** Blume (Plate 6, 7a)

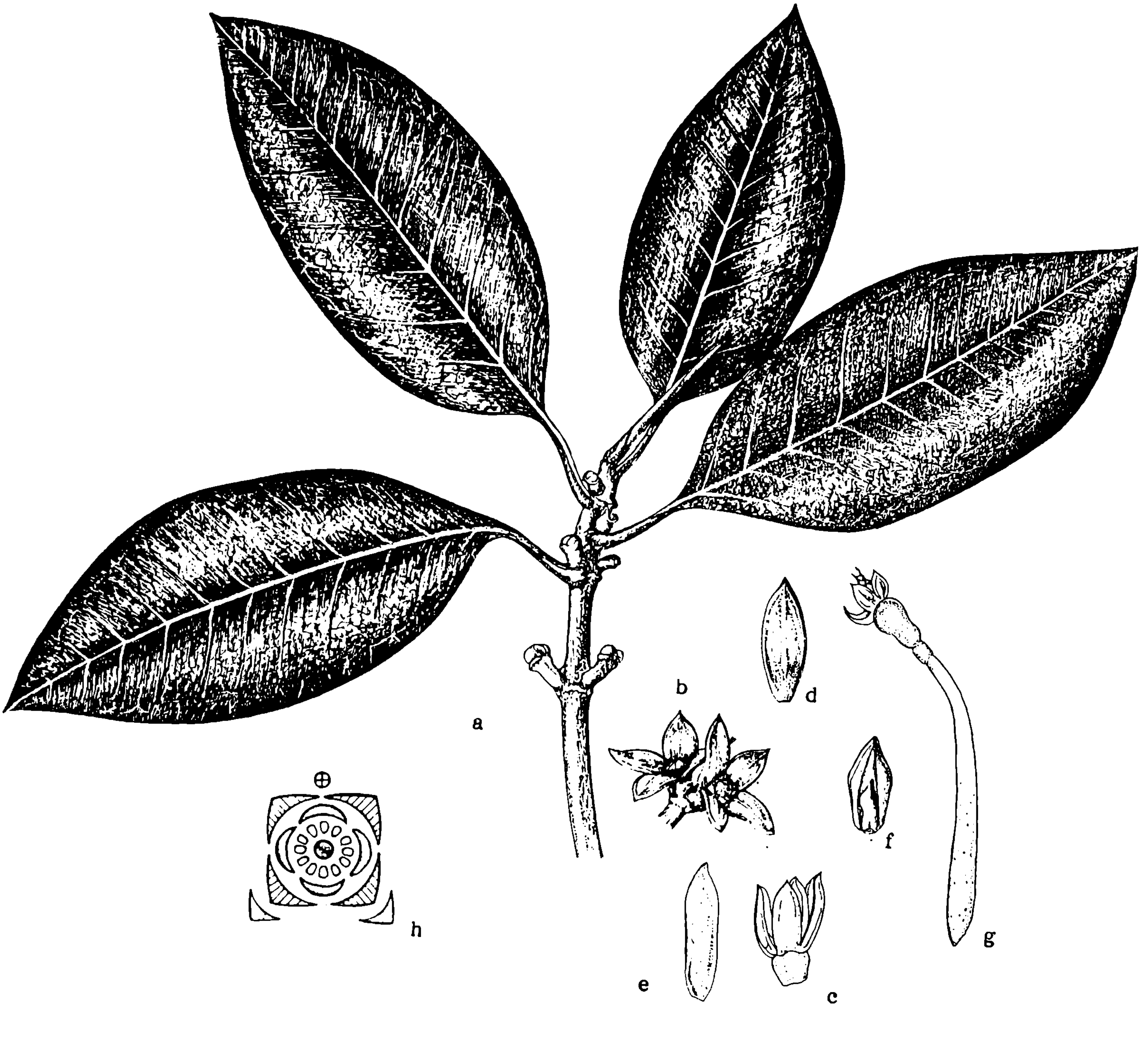
R. candelaria De

R. conjugata (non L.) Arn.

Plate 6.

Morphological features of Rhizophora apiculata Blume

a) Shoot with developing buds (x 3/4)
b) Inflorescence (x 1)
c) Flower, side view (x 1)
d) Sepal (x 1.5)
e) Petal (x 3)
f) Stamen (x 2.25)
g) Propugule (x 1/3)
h) Floral diagram


a
b
c
d
e
f
g
h

A robust columnar tree that establishes in the water front or mid tidal area. Strong prop roots send flying butresses. Bark-grey to black, rough.

Leaves: dark glossy green, elliptic, flat, about 13-14 cm long, 6.5-7.0 cm wide, petiole 2.5 cm on an average.

Inflorescence: Single dichotomous branch having two sessile flowers on stout peduncles, borne below the leafy crown, in the axil of a fallen leaf; buds robustly ellipsoidal, brownish.

Flowers: Sessile with a pair of massive corky bracteoles; sepals-4, thick, corky in texture, brown, concave, diameter of flower 25-28 mm; petals-4 glabrous; stamens-12, sessile, each stamen dehices by a ventral flap which exceed the stigma in height, style very short less than 1.0 mm; stigma bilobed; ovary - half inferior, 2 celled, each with 2 ovules.

Fruits: 2 cm long, bulbous, corky, Hypocotyl-25-28 cm cylindrical, stocky, dark green with occasional brown lenticels, root tip rounded or blunt.

**Rhizophora mucronata** Lamarck (Plate 7b, 8)

R. macrorhiza Griff

R. longissima Blanco

R. latifolia Mig.

R. mucronata var Typica Hochreter.

Columnar tree mostly occupying water front with characteristic tangle of prop roots usually in rows as pure stands; bark grey or brown, rough; height - 4 to 8 m.

Plate 7.

a) Top: Rhizophora apiculata
from Location M-3

b) Bottom: Rhizophora mucronata
Inflorescence

Leaves: Opposite, broad, elliptic to oblong; 10-15 cm long, 5-10 cm wide, petiole 2.5 - 3.0 cm; leaf bright green in colour, margin smooth, reddish brown spots evenly distributed on the under side; leaf tip with an erect mucronate tip 2-5 mm long.

Inflorescence: Dichotomous branching with 2-4 buds per inflorescence buds pale green, smooth, about 1.5 cm long; bracts and bracteoles - smooth, minute; peduncles 4-6 cm long;

Flowers: sessile, sepals - 4, coriaceaous; petals - 4, 10 mm long, 3 mm wide, woolly, involute, lanceolate, pale yellow; stamens - 8, style - very short (1.0 - 1.5 mm)

Fruit: Pyriform, vertical grooves in the proximal portion, 4-5 cm long; Hypocotyl - cylindrical, long upto 50 cm, smooth and green with brown lenticels, tip pointed.

**Bruguiera gymnorrhiza** Lamarck. (Plate 9, 14b)

Rhizophora gymnorrhiza Linnaeus

Rhizophora tinctoria Blanco

Bruguiera rheedi Bl.

Bruguiera conjugata Merr.

Tall columnar trees reaching 10-12 m in height in slightly elevated ground, in association with other species of Bruguiera. Short butresses at the base, Kneed roots present, bark-rough, fissured, black, terminal shoots, short; brownish.

Plate 8.

Morphological features of Rhizophora mucronata Lamarck

a) Shoot with inflorescence (x.5)

b) Inflorescence (x1)

c) Individual flower, view from top (x2/3) in the petals

d) " after petals are shed

e) Stamen (x2)

f) Propagule (x1/2)

g) Floral diagram

Plate 9.

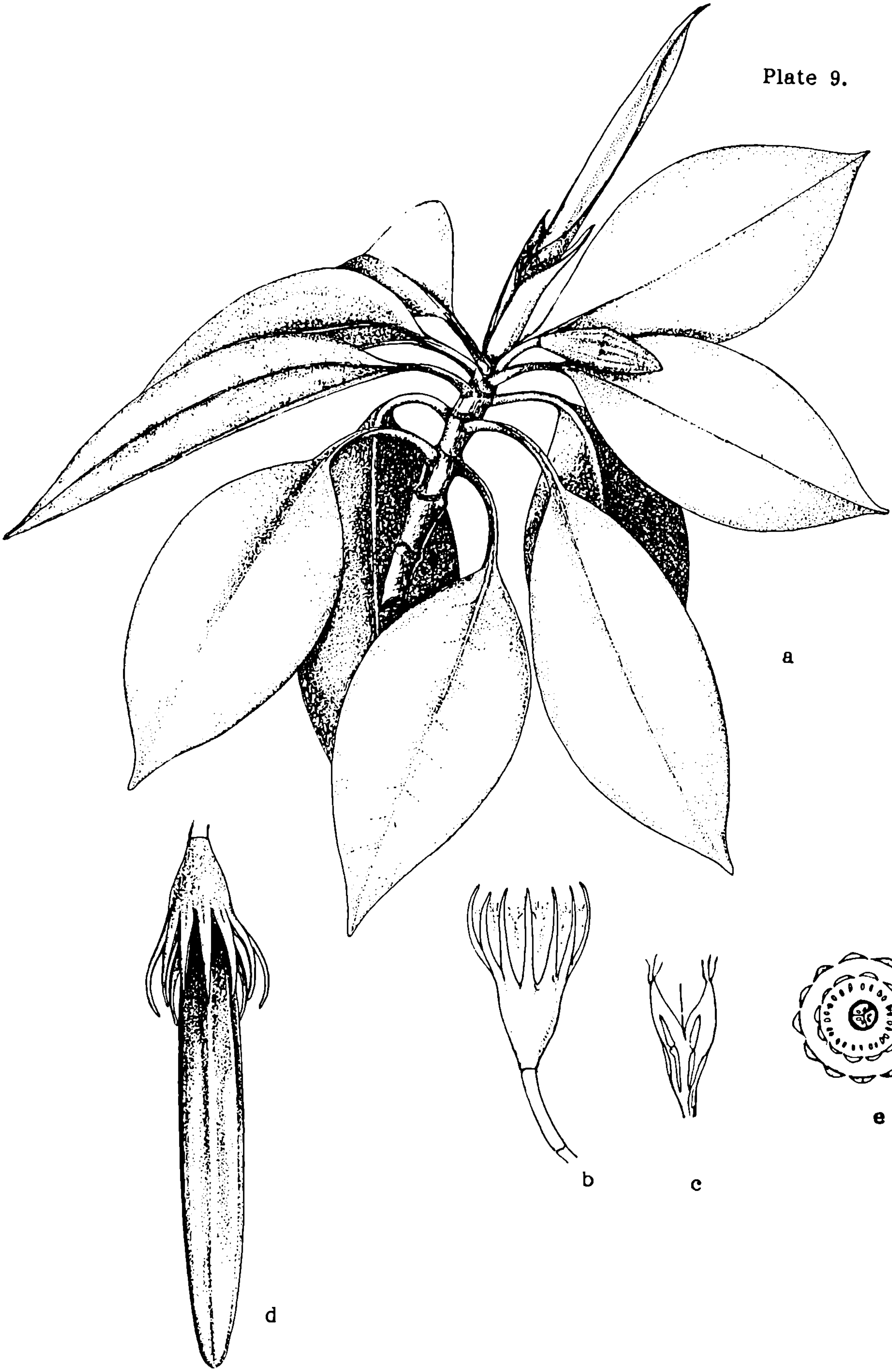
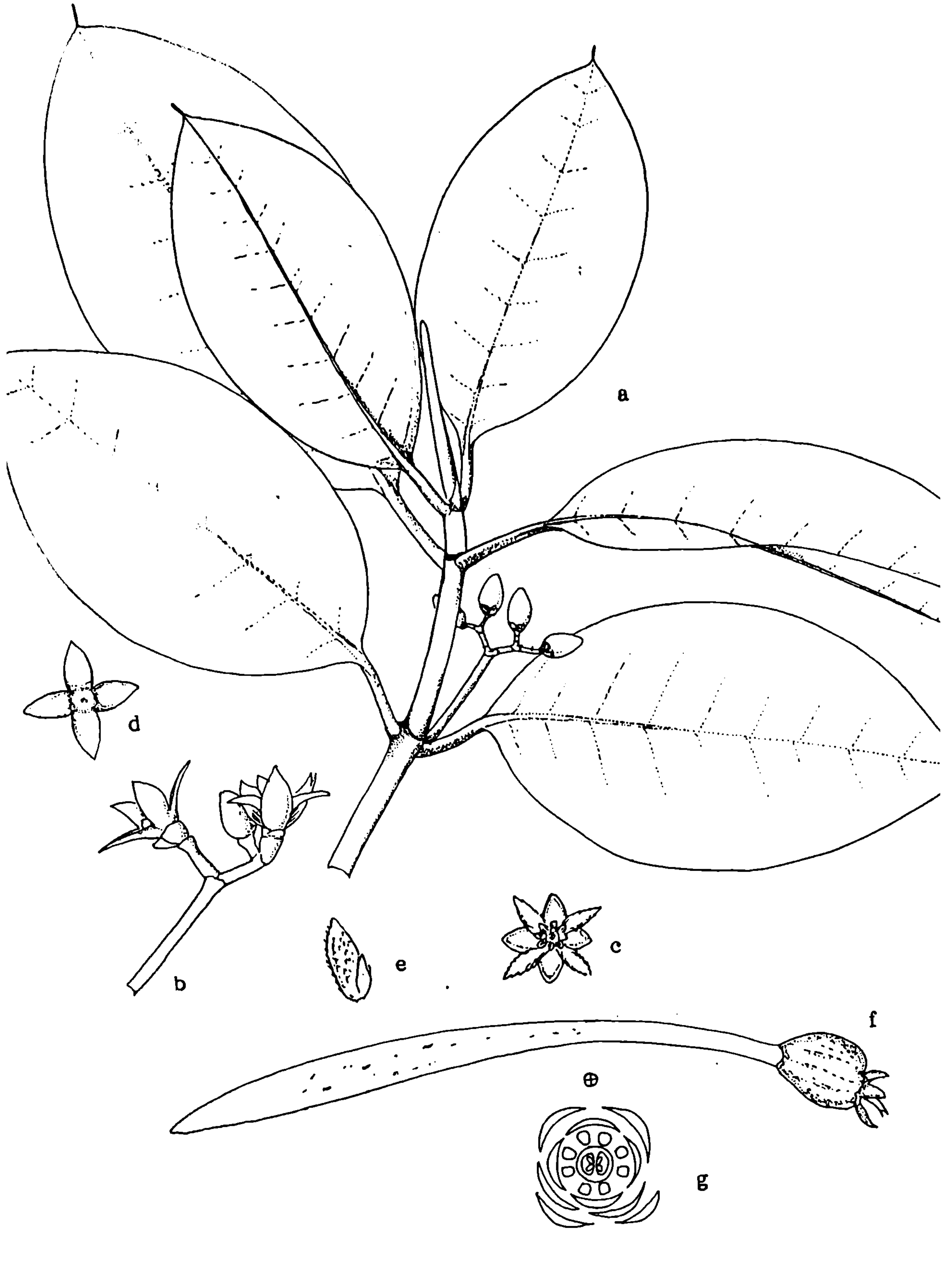


Plate 8.



Leaves: elliptic, oblong, coriaceous, about 15 cm by 4.5 - 5.0 cm, petiole 3-4 cm; petioles and young shoots with a waxy coat reddish tinge on the underside of petioles and midrib; upper side of leaf green to dark green.

Flower: Solitary, 3.5-4.5 cm long, nodding, pinkish or reddish calyx cup and lobes, lobe tips-green, lobes - 11-13, remains erect in fruit; petals - 11-13, about 12 mm long from base, petals bilobed, bristle in the sinus between the lobes, tip of petal lobes acute, each with 3 filamentous appendages; stamens, twice the number of petals, anther linear.

Ovary inferior, adnate to lower part of calyx tube, 2-4 celled, each cell with 2 ovules, style fitiform. Stigma obscurely 2-4 lobed.

Hypocotyl: Stout, cylindrical, cigar shaped, about 14 cm long with 14 mm diameter, brownish green, slightly ridged, slightly rough surface.

**Bruguiera sexangula** (Lour.) Poir. (Plate 10, 13b)

Rhizophora sexangula Lour.

Bruguiera sexangularis Spreng.

Rhizophora polyandra Blanco

Rhizophra eriopetala Steud.

Erect columnar tree reaching 6-7 m (at Cochin); with short buttresses near base, bark smooth, grey, with lenticels, a few linear fissures present.

Leaves: elliptic-oblong; base acute-obtuse; about 12-14 cm x 4.5-5.5 cm; flat, petiole 2.5-4.0 cm, colour parrot green on the upper side, lighter green below, petiole and young twigs light green; stipule green or yellowish.

Flower: Solitary on one axil or both axils, at the node; nodding; 2.5-4.0 cm long; pedicel 8-12 mm, calyx yellow-green turning yellow brown, calyx tube 10-15 mm long, distinctly ridged, lobes-10, same length as tube; Petals - densely fringed with hair along outer margin from base to apex, bilobed with a distinct bristle from the sinus; lobe tip obtuse, Stamens twice the number of petals (ie. 20), ovary inferior, style-fili form, anther linear.

Hypocotyl; stout, thick, blunt, light green with the attached calyx lobes spreading like an umbrella. Surface smooth unlike in *B. gymnorrhiza* Size : 6-8 cm x 14-15 mm.

***Bruguiera cylindrica*** (L.) Blume (Plate 11, 13a)

*Rhizophora cylindrica* Linnaeus

*Mangium minus* Rumph

*Mangium caryophylloides* Rumph

*Rhizophora caryophylloides* Burm.

*Rhizophora ceratophylloides* Gmel.

*Bruguiera caryophylloides* Bl.

*Bruguiera malabarica* Arn.

*Kanilia caryophylloides* Bl.

Plate 9.

Morphological features of *Bruguiera gymnorrhiza* Lamarck.

a) Shoot with bud (x1/2)

b) Flower, side view (x3/2)

c) Petal (x2)

d) Propagule (x3/4)

d) Floral diagram

Plate 10.

Morphological features of Bruguiera sexangula (Lour.) Poir

a) Shoot with bud (x 1/2, approx.)

b) Individual flower (x 0.7)

c) Petal (x 2)

d) Propagule (x 1/2)

e) Floral diagram

Plate 10

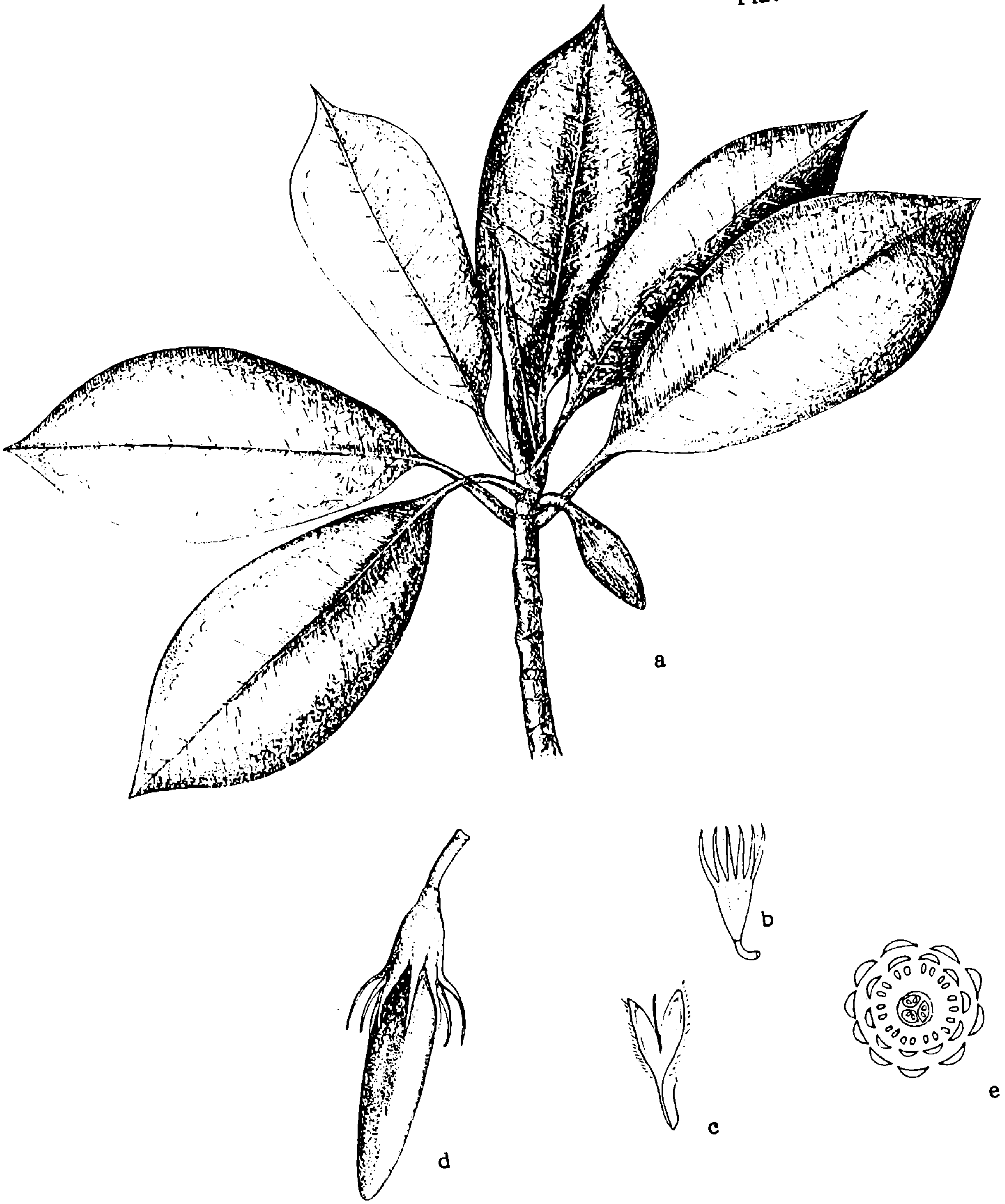


Plate 11.

Morphological features of *Bruguiera cylindrica* (L.) Blanco

a) Shoot with flowers (x3/4)

b) Inflorescence (x2)

c) Petals (x4)

d) Propagule (x1)

e) Floral diagram

Plate 11.

Plate 12.

Morphological features of *Aegiceras corniculatum* (L.) Blanco.

a) Shoot with flowers (not to scale)

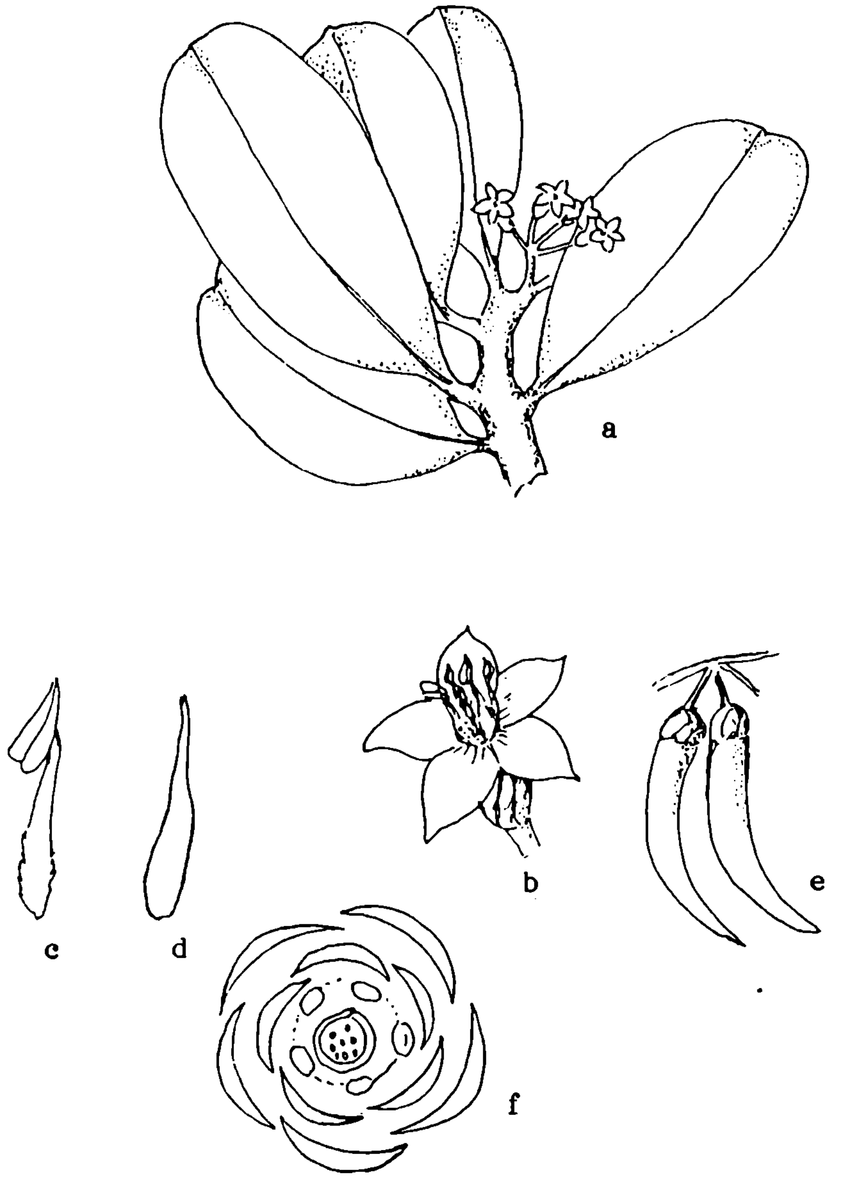
b) Flower, view from top (x2)

c) Stamen (x3)

d) Ovary (x4)

e) Propagule (x.75)

Plate 12.



Reaching 5-12 m in height, bark dark grey, in the landward fringe zone of a mangrove swamp.

Leaves: Opposite decussate, coriaceous, acute, greenish flowers in cymes, three flowered, usually 8 recurved calyx lobes, green, persistent, recurved in fruit, calyx tube smooth, companulate, adnate to the ovary, valvate, petals 8, oblong, each petal 2 lobed, 3 bristles at the tip of each lobe and a bigger bristle in the sinus of the two lobes, petals fringed with white hairy appendages in their outer margins, stamens twice the number of petals in pairs within each petal, filament filiform 1-2 mm long, anthers linear, 0.5 mm long, ovary inferior, 4 celled 2 ovules in each cell, style filiform stigma 3 lobed, hypocotyl cylindrical, 8-15 cm long, slight curved with reflexed calyx lobes.

MYRSINACEAE

**Aegiceras corniculatum** (L.) Blanco (Plate 12)

A. majus Gaertn.

A. malaspinaeae Du.

Malaepinaeae lauri folia Presel.

Rnizophora corniculatum, Stickman.

Occurs as shrubs on the edges of creeks in a mangrove habitat.

Leaves: Alternate, shining, flowers white with a pungent smell, calyx made of 5 imbricate lobes, lobes twisted to the left, overlapping to the right, lobes persistant with the fruit, corolla tube short, petals villous, lobes 5, overlapping to the right in the bud, afterwards re-curved, filaments linear, connate below, villous, anthers cordate, lanceolate, transversely sepetate, ovary fusiform, narrowed into an elongate style, ovules 10, immersed in a central globose placenta. Fruit 3-4 cm long, appear like claws; exhibit crypto-vivipary.

EUPHORBIACEAE (Plate 14)

**Excoecaria agallocha** Linnaeus

*E. affinis* Endl.

*E. camettia* Wild.

*E. oralis* Endl.

Shrubs and trees reaching 4-5 m in height, bark grey, smooth with prominent lenticels, Twigs and petiole exude, milky latex, poisonous, usually occurring in the landward fringe of the mangrove area.

Leaves: Simple, alternate, spirally arranged, ovate, elliptic, acute, dioecious.

Inflorescences axillary, pale green, 4-8 cm long initiated like a cat kin like structure within the leaf bearing portion of shoot, some times not expanding till the leaf falls. Male inflorescence longer than that of female; with a series of spirally arranged bracts, each bract subtending a male flower each with 3 lacinate tepals below 3 yellow stamens, anther, bilocular, basifixed. Female inflorescence occupying the terminal part, ovary tricarpellary, with one ovule in each carpel, style 3, fruit, a capsule.

AIZOCEAE

**Sesuvium portulocastrum** Linnaeus

Perennial succulent herb; more abundant near the fringe zone, leaves opposite, 1-5 cm length, fleshy, linear to narrowly obovate, the petioles connected by a stipuliform membrane, calyx lobes 5, with horn like appendages, lanceolate persistant, coloured purplish within, hyaline on the margin , petals nil, stamens many, inserted round the top of calyx tube, filaments connate at base, ovary superior, 3 locular, ovules numerous on axile placentation, style 3, fruits an ovate membranous 3 celled capsule, dehice transversely, about 8 mm in length, axis and placenta persistant, seeds many, reniform, testa smooth.

CHENOPODIACEAE

**Suaeda maritima** (L.) Dumort.

Chenopodina indica Wt.

An annual mostly found in the back mangrove area, leaves fleshy, narrowly linear, flowers bracteolate, minute, pentamerous actionopmorphic, sessile, perianth lobes 5, united, lobes curved in, stamens 5 adnate with perianth lobes near the base of the ovary, anther large with 4 locules, ovary superior, style absent, stigma - 3, fruit a small membranous utricle.

RHIZOPHORACEA

**Kandelia candel** (L.) Druce

K. rheedi Wight and Arnold

Medium sized tree of about 5 m (in Kerala); Bark smooth, greyish to brown; buttresses and pneumatophores not present.

Leaves: oblong-elliptic; 8-10 cm long, 3.0-4.5 cm broad; apex obtuse, base cuneate, margin entire and smooth, Petiole 10-15 mm long; stipules small about 2 cm.

Inflorescence: axillary, branching with 4 or more flowers; peduncles about 3-5 cm long, slender.

Flower: Bracteoles form a cup below the calyx tube, size of flower 1.5 to 2 cm long, white; calyx lobes - 5, linear, about 15 mm long; petals, glabrous about the same length of calyx, slender narrow with two lobes, filamentous appendage between the lobes, tip of lobes with 3-4 long filaments, stamens numerous from the base of calyx with varying heights, anthers slender; ovary inferior, unilocular, style filiform, 10 mm.

Fruit: 1.5 to 2 cm long with persistent calyx lobes reflexed; Hypocotyl much slender tapered at both ends, about 20 cm long, pointed tip. Surface smooth, light green.

SONNERATIACEAE (Plate 15)

**Sonneratia caseolaris** (L.) Engler

Medium sized tree of 3-4 m at (Location $M_3$) in Cochin; about 8 m at Kumarakom; Bark slightly fissured, grey; up right pneumatophores broad at barse and pointed at tip.

Leaves: Opposite, obovate about 5-7 cm long; margin entire; petiole short, slightly pinkish, this colour spreads to the mid rib near base.

Flowers: Solitary, terminal, 35 to 40 mm in height. Calyx cup shaped, green, smooth, lobes-6, pointed, thick. Petals 6, red, linear, stamens-numerous, with long red filaments about twice the length of flower, style also very long, protruding out of the flower distinctly.

Fruit: Shining green, cup shaped with persistent calyx on the top, 6 cm diameter.

Plate 13.

a) Top: *Bruguiera cylindrica*

One of the commonly occurring species of Bruguiera in the study area

b) Bottom: *Bruguiera sexangula*

A rare species, now located in the study area.

Plate 14.

a) Top: Excoecaria agallocha

One of the widely distributed species.

b) Bottom: Bruguiera gymnorrhiza

This species is found only in a few loations in small numbers in the study area.

Plate 15.

a) Top: *Sonneratia caseolaris*

Shoot with flower bud opening

b) Bottom: Same species with opened up flower with numerous stamens

(This species is becoming rare in the study area)

# 4. CLIMATIC AND EDAPHIC FACTORS

## CLIMATIC FACTORS

Blasco (1984) observed that there is a general assumption that mangroves develop best in tropical estuaries which receive good amount of rainfall distributed evenly throughout the year and that aridity is a limiting factor in many regions of the World. However, as pointed out by him, local variations in bio-climatic conditions also play an important role in determining the extent of mangrove area and number of species. In this connection he stressed the need for preparing a climatic identity card in the form of an ombrothermic diagram for each mangrove locality.

The broad climatic conditions prevailing in the study area are follows:

The Cochin estuarine system falls within the tropical summer rainfall zone. ' Most of the coastal areas in India, Burma and Thailand come under this climatic regime. The climatic conditions at Cochin are mostly influenced by the southwest monsoon during June to September and to a lesser extent during the northeast monsoon during October-December. Generally there is a reversal in the direction of the wind systems during the above seasons.

The climatic diagram for Cochin for the year 1991 is presented in Fig. 7. The mean atmospheric temperature increased from 27°C in January to 30°C during April-May and decreased to 26°C in July. Thereafter there was a gradual increase upto November (28°C) and then dropped to 26°C in December. June recorded the heaviest rainfall and 75% of the annual total rainfall occurred during the southwest monsoon season. There was a secondary peak in rainfall during October-November. The months, January to March were practically dry.

The average maximum, average minimum, absolute maximum and absolute minimum temperatures recorded for each month of 1991 along with percentage of relative humidity are given in Table-2.

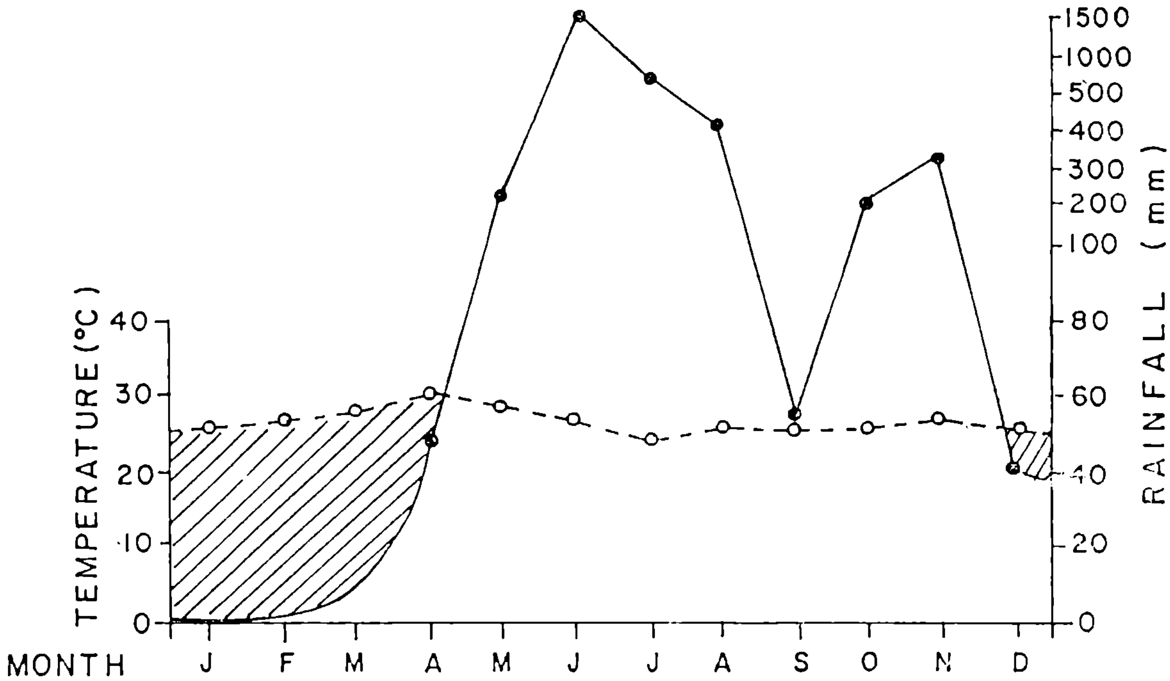
In order to have an average picture of the climatic conditions for a 50 year period the data on the relevant parameters is presented in Tab.-3 & Fig.8. As could be seen from the Table, Daily mean temperature increases from 26.7°C in January to 28.7°C in April and decreases towards July and recovers back to 26.7°C in December. Lowest minimum temperatures have been indicated in January. The rainfall is maximum during the months June-July with traces during January to March. 67% of the annual total rainfall occurs during the monsoon months. A secondary peak is observed in October. Mean wind speeds range from 5.6 to 9.2km/hr.

Discussion

The climatic data shows that the average temperature is above 19°C and the average minimum temperature of the coldest month is about 13°C. The temperature difference between average minimum and maximum are about 7°C. The number of arid months are less than 4. The above conditions are not therefore limiting factor for the mangroves of Cochin

Table–2. Climatic data for Cochin for the year 1991

| Month | Temperature °C | | | | Relative Humidity % |
|---|---|---|---|---|---|
| | Average Maximum | Average Minimum | Absolute Maximum | Absolute Minimum | |
| January | 31.6 | 22.0 | 33.0 | 19.0 | 70 |
| February | 32.5 | 24.0 | 34.0 | 21.0 | 73 |
| March | 32.8 | 25.0 | 33.0 | 24.0 | 75 |
| April | 33.0 | 26.8 | 35.0 | 23.0 | 80 |
| May | 33.0 | 27.0 | 36.0 | 25.0 | 85 |
| June | 30.1 | 24.5 | 33.0 | 23.0 | 90 |
| July | 28.6 | 23.5 | 31.0 | 22.0 | 95 |
| August | 29.0 | 23.5 | 31.0 | 22.0 | 95 |
| September | 30.2 | 25.0 | 33.0 | 24.0 | 90 |
| October | 30.0 | 25.0 | 31.0 | 28.0 | 85 |
| November | 31.5 | 24.5 | 32.0 | 23.0 | 85 |
| December | 31.0 | 21.0 | 32.0 | 18.0 | 80 |




| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINFALL (mm) : | 0 | 0 | 0 | 50 | 230 | 1500 | 636 | 440 | 54 | 200 | 310 | 40 |
| NO. OF DAYS : | 0 | 0 | 0 | 4 | 7 | 23 | 18 | 15 | 2 | 5 | 7 | 1 |
| TEMP. (°C) : | 27 | 28·5 | 29 | 30 | 30 | 27·5 | 26 | 26·5 | 27·5 | 27 | 28 | 26 |

**Fig. 7.** Ombrothermic diagram for Cochin.

Table-3.

CLIMATIC DATA FOR COCHIN

(Average for 50 years)

| Data | Months | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | F | M | A | M | J | J | A | S | O | N | D |
| Mean of: | | | | | | | | | | | | |
| Rainfall (mm) | 14 | 20 | 40 | 107 | 282 | 745 | 633 | 414 | 267 | 335 | 154 | 49 |
| No. of days | 1 | 1 | 3 | 6 | 12 | 25 | 25 | 21 | 14 | 14 | 9 | 3 |
| Mean of: | | | | | | | | | | | | |
| Daily Temp. | 26.7 | 27.4 | 28.4 | 28.7 | 28.3 | 26.4 | 25.9 | 26.0 | 26.2 | 26.7 | 26.9 | 26.7 |
| Daily Max. Temp. | 30.4 | 30.6 | 31.2 | 31.4 | 30.9 | 29.0 | 28.1 | 28.2 | 28.3 | 29.3 | 29.8 | 30.2 |
| Daily Min. Temp. | 23.0 | 24.2 | 25.7 | 26.0 | 25.7 | 23.9 | 23.7 | 23.8 | 24.1 | 24.1 | 24.0 | 23.3 |
| Lowest Min. Temp. | 17.8 | 19.4 | 21.1 | 21.7 | 21.1 | 20.6 | 21.1 | 21.1 | 21.1 | 26.1 | 19.4 | 19.4 |
| Humidity % | 70 | 73 | 75 | 75 | 80 | 86 | 87 | 86 | 84 | 83 | 79 | 73 |
| Mean Wind Speed (Km/Hr.) | 6.9 | 8.2 | 9.2 | 9.2 | 9.0 | 7.9 | 8.4 | 8.4 | 7.7 | 6.4 | 5.6 | 6.1 |

Source: Ernakulam dist. Gazetteer.

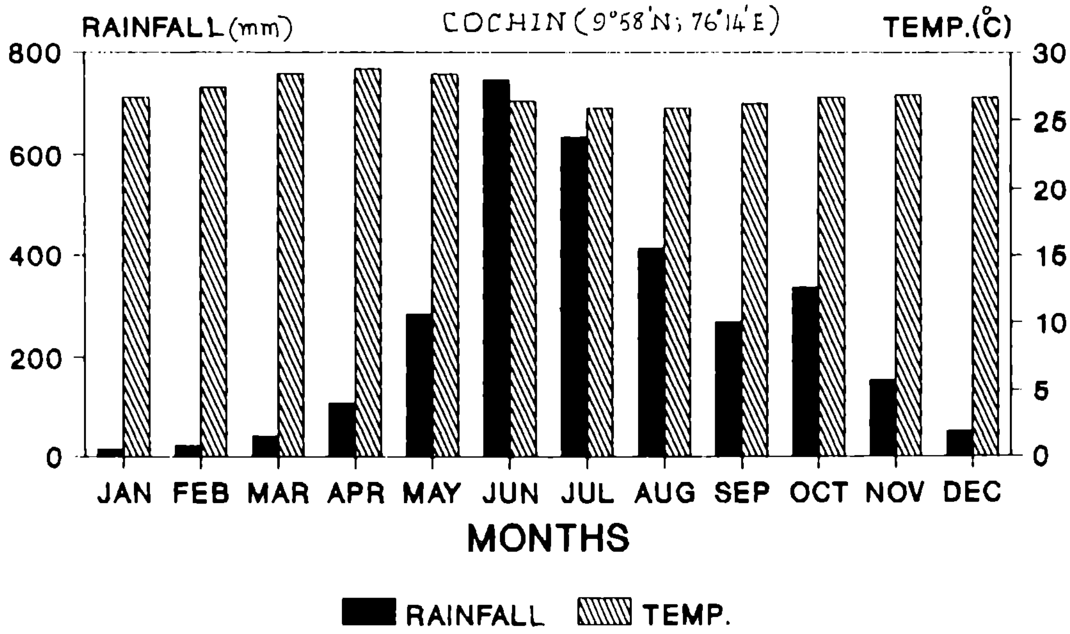



**Fig. 8.** Rainfall and atmospheric temperature (Average for 50 years)

as per the criteria proposed by Blasco (1984). He pointed out that along the west coast of India the ratio between precipitation and avapotranspiration is greater than a factor of 0.75 indicating a very humid condition which is favourable to mangroves unlike in Gujarat where aridity and low rainfall act as the limiting factors.

It has been observed throughout the world that best development of mangrove ecosystem occurs where upper tidal areas are exposed to a continuous supply of freshwater (Saenger et al., 1983). Blasco (1984) stated that this condition is possible where (i) rainfall exceeds evaporation through the year or (ii) large freshwater catchments allow strong dilution of estuarine water or (iii) where large freshwater catchments and heavy seasonal rainfal provide regular and prolonged freshwater flooding of the tidal zone. At Cochin both conditions (i) and (iii) are favourable to mangroves to flourish but for anthropogenic pressure

## SOIL CHARACTERISTICS OF MANGROVE AREAS

The need for understanding edaphic factors in addition to or in relation to climatic factors was stressed by Blasco (1975, 1984) while evaluating the functioning of mangrove ecosystems. In his study on the distribution of mangroves in India he gave indications about the soil properties in different regions. He pointed out that soil salinities between 40-80 ppt restricted size as well the number of species of mangroves and that 'blanks' are found in areas having salinities beyond 90 ppt.

Karmarkar (1985) has given a brief review of the mangrove soil status in Maharashtra region with reference to the physiological adaptation of different species of mangroves.

Results of the physical and chemical characteristics of the mangrove soils studied in different locations are presented in Tables-4 & 5.

### Texture of the soils

Sand-silt-clay fractions showed an admixture of proportions in different locations. In general, sand fraction dominated the soils with the proportion of silt and clay varying.

Within a locality also, variations were observed in different sites. For example in the recently sea accreted formation north of Vypeen (Location N-1) clayey sand was dominant in slightly interior site whereas silty sand was dominant in the peripheral regions. Here the principal vegetation is *Avicennia officinalis*.

Similarly, at Puduveyppu (Location N-2) silty sand was dominant in the areas occupied by Acanthus ilicifolius and clayey sand in the zone dominated by Rhizophora mucronata and Bruguiera spp. While at Valappu (Loation N-4) silty sand is the characteristic the sites at Narakkal, (N-5) were clayey sand.

Chemical characteristics

The present status of soil chemical characteristics at selected important locations in the study area as per the data collected during 1990-91 is as follows:

Location M-1 (Mangalvanam)

The soil reaction is slightly below neutral. The exchangeable cat-ions (Na, K and Ca) are moderate compared to coastal saline soils. The organic carbon is high. However, since the clay content is less, the Cation Exchange Capacity (CEC) is also moderate. As regards available nutrients it is estimated that available Phosphorous and Potassium are 50.0 Kg/ha and 270.0 Kg/ha respectively. The soil has a moderate EC of 5.6 mm hos/Cm.

Location N-1 (Avicennia zone)

In this location the soil is saline with an EC of 15.5 mm hos/Cm and pH of 7.92. The organic carbon content is high and also available nutrients such as P (48 Kg/ha) and K (223 Kg/ha). The CEC is 17.63 meq/100g which is slightly low but the exchangeable cat-ions indicate that the area is fertile.

Table-4. Textural composition of mangrove soils at different locations.

| Location / Site | Sand % | Silt % | Clay % | Classification |
|---|---|---|---|---|
| Location S | 60 | 25 | 15 | Silty sand |
| " S-1 | 16 | 62 | 22 | Clayey silt |
| " S-4 | 60 | 26 | 14 | Silty sand |
| " S-5 | 57 | 28 | 15 | Silty sand |
| Location M-1 | | | | |
| Site (i) | 73 | 16 | 11 | Silty sand |
| Site (ii) | 83 | 5 | 12 | Clayey sand |
| Site (iii) | 85 | 6 | 9 | Clayey sand |
| Location N-1 | | | | |
| Site (i) | 72 | 16 | 12 | Silty sand |
| Site (ii) | 62 | 24 | 14 | Silty sand |
| Site (iii) | 46 | 18 | 36 | Clayey sand |
| Location N-2 | | | | |
| Site (i) | 44 | 34 | 22 | Silty sand |
| Site (ii) | 47 | 16 | 37 | Clayey sand |
| Site (iii) | 76 | 4 | 20 | Clayey sand |
| Loction N-4 | 36 | 43 | 21 | Sandy silt |
| Location N-5 | | | | |
| Site (i) | 75 | 8 | 17 | Clayey sand |
| Site (ii) | 84 | 5 | 11 | Clayey sand |
| Site (iii) | 78 | 8 | 14 | Clayey sand |

Table -5. Average chemical composition of mangrove soils at selected locations

| Location | pH | Conductivity (mm hos/cm) | CEC (meq/100g) | Organic Carbon % | Available Nutrients (kg/ha) | | Exchangeable cat-ions (meq/100gm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | P | K | Na | K | Ca |
| N-1 | 7.92 | 15.5 | 17.63 | 2.45 | 48 | 223 | 4.53 | 0.45 | 6.3 |
| N-2 | 7.53 | 5.2 | 20.64 | 1.86 | 71 | 186 | 2.51 | 0.58 | 11.6 |
| N-5 | 7.49 | 8.7 | 21.36 | 1.35 | 34 | 205 | 2.05 | 0.40 | 15.0 |
| M-1 | 6.94 | 5.6 | 19.2 | 1.8 | 50 | 270 | 8.48 | 0.54 | 15.0 |

Location N-2 (Bruguiera - Rhizophora zone)

In this zone soil reaction is slightly above neutral and EC is at 15.2 mm hos/Cm. The CEC is moderate but organic carbon content is high. Available P and K was estimated at 71 and 186 kg/ha respectively. The soil is considered to be fertile. This zone is having the maximum numbers of stands of *Bruguiera* spp. and *R. mucronata* along with lesser numbers of *A. officinals.*

Location N-5 (Narakkal)

At this location also the soil is just above neutral, less saline and having moderate CEC. Organic carbon content is at 1.4% and available nutrients P and K was estimated at 34 and 205 Kg/ha respectively.

Discussion

At the Pichavaram mangrove area in the south east coast, Blasco (1985) observed pH at 7.5, conductivity at 39.8 and cat-ions, Na, K, Ca at 71.5, 5.66 and 1.64 respectively at a zone having mixed vegetation comprising six species of mangroves. In the back mangrove area dominated by species of *Suaeda* and *Sesuvium* he observed high content of Na and Cl which could be visibly seen as powderly crust on surface. He observed relatively low sulphur and carbon content in a predominantly saline clayey soil.

Karmarker (1985) stated that the soils supporting mangroves are broadly distinguished as sandy loams and silty loams and there is great variability from one region to another. Besides, changes in pH, Chloride content in relation to rainfall and other factors add to this variability (Bharucha and Navalkar, (1942).

In general pH varies between 7-8, but in Pichavaram A. marina is able to grow in acidic soil having pH in the range 3.4 to 4.5 (Blasco, 1975).

Karmarkar (1985) stated that sodium is the dominant cat-ion in water and also in the soil through which seawater percolates and that such soils are characterised by high Sodium Adsorption Ratio and Exchangeable Sodium percentage. Which affects the availability of water to plants. Topography of the region and human interference are considered by him as responsible for the variations.

At Deogad and Mumbra in Maharashtra coast, Kotimere and Bhosale (1979) observed the mangrove soils to be acidic but the quantum of cat-ions such as Na, K and Ca to be high. A similar situation was observed by Mall et al. (1985) in Andaman islands.

Sah et al. (1985) who studied the soil properties of Prentice and Lothian areas in Sunderbans reported that pH and EC of mangrove muds showed alkaline reaction and indicated the presence of high content of soluble salts. The exchange behaviour of the soil was moderate to high CEC. (16.46 to 23.17 me/100 g). This they attributed to the fine texture of the mud. Further they observed low organic matter content and low exchangeable Na (0.27 to 8.34 me/100 g). On the other hand Ca and Mg were more strongly represented in the exchange complex. Variations in Eh from -75 to +150 mV were attributed to partial or complete submergence of the mangrove areas and that partial submergence at Lothian belt is favourable to growth of micro organisms.

Elsewhere, outside India, Sukardjo (1982) observed that in Cimanuk delta mangroves in Indonesia, the substrata were predominantly loamy and slightly acidic towards landward side and that the CEC was high (37-53 meq/100 g). Organic matter ranged from 6.64 to 23.16% and exchangeable cat-ions such as Na was very high (105.68 to 263.54 me/100 g)

# 5. ENVIRONMENTAL PARAMETERS

# ENVIRONMENTAL PARAMETERS

The mangrove localities studies as indicated in Fig. 3 are situated not far away from the Cochin bar mouth except the southern stations. The canals and creeks that pass through the mangrove locations are connected to the backwater estuarine system. Hence the hydrographical parameters are closely related to the seasonal changes and dynamism in the estuary as a whole. The hydrography of this estuarine system has been studied earlier by a number of workers notably by Ramamirtham and Jayaraman (1963); Sankaranarayanan and Qasim (1969) and Ramamirtham *et al.* (1986).

The environmental parameters observed in selected mangrove locations are presented here to give a general picture of the seasonal changes.

## Location S-5

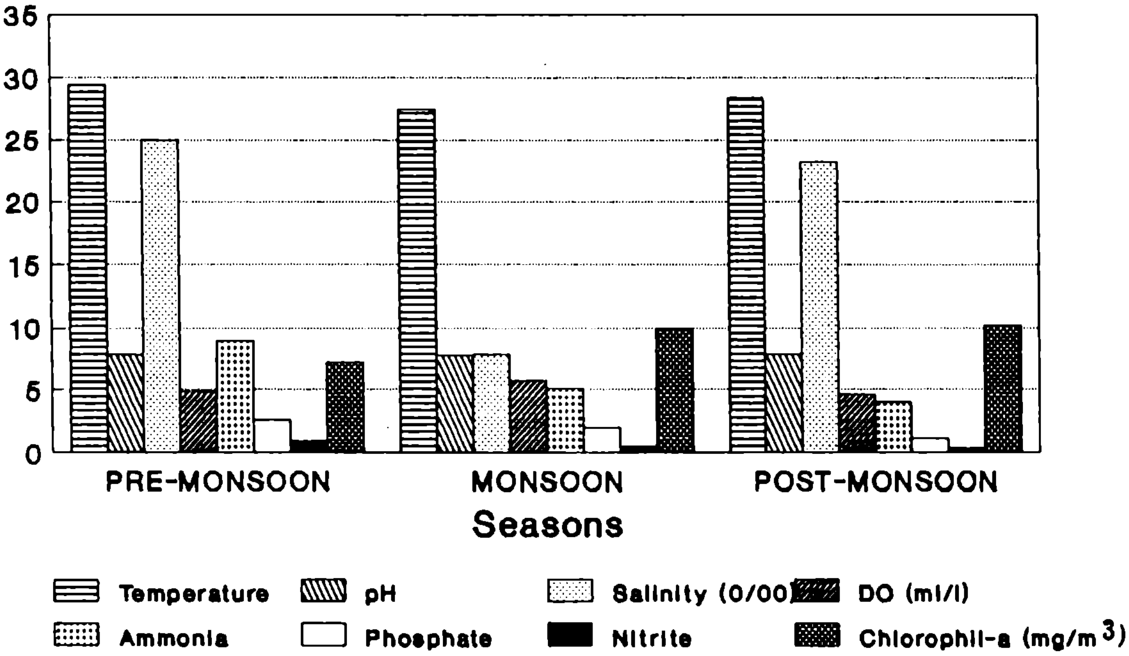
The mean values from surface samples collected during 1988 and 1989 are given in Table- 6. . Surface temperature during premonsoon months had a mean value of 29.44°C which dropped to 27.5°C during monsoon season and recovered to 28.42°C during post monsoon months. The pH values did not show much variations. Dissolved oxygen values were high during monsoon months compared to other seasons. Ammonia and nutrients showed higher values during premonsoon months. This is attributed to the heavy premonsoon showers and discharge from the rivers. These parameters and their fluctuation are also presented in Fig. 9.

Table -6. . Environmental parameters at Station S-5.

| Season | Temp °C | pH | Salinity ‰ | Dis. $O_2$ (ml/l) | Ammonia | Phosphate | Nitrite | Chlorophyll a ($mg/m^3$) |
|---|---|---|---|---|---|---|---|---|
| | | | | | (µg at/l) | | | |
| Premonsoon | 29.44 | 7.86 | 24.97 | 4.90 | 9.00 | 2.66 | 0.94 | 7.20 |
| Monsoon | 27.5 | 7.77 | 7.86 | 5.76 | 5.10 | 1.99 | 0.48 | 10.00 |
| Postmonsoon | 28.42 | 7.86 | 23.25 | 4.57 | 4.04 | 1.17 | 0.34 | 10.20 |

Average values from surface samples.

Fig. 9. Environmental parameters at station S-5. (averages)




(/ug.at./l)

(Pooled average for 1988-89)

Location N-1

At this location, the monthly mean values of temperature, salinity and oxygen values monitored during 1990-1991 are presented in Table-8.

Surface temperature increases from January to reach a peak in May and drops to low values during the peak of monsoon in July and therefter increases again during October-November and shows a small decrease during December.

Surface salinity values showed a drastic reduction during monsoon months, but gradually recovered to original values in the subsequent months with a slight lowering during in November which is related to North East monsoon showers.

At this location, Dissolved oxygen values showed significantly low values during July 1990 and September 1991. This is attributed to the intense coastal upwelling in the Arabian sea during this period and its influence on the estuary. Fluctuations in these parameters are given in Fig. 10.

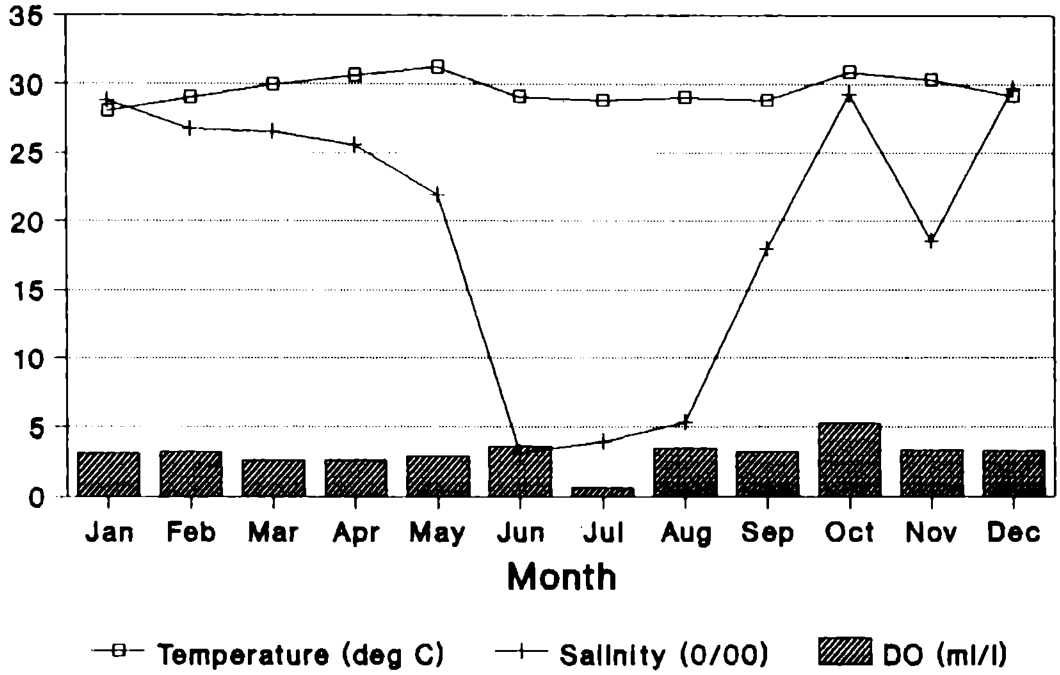
Location N-2

Here the tidal creeks are shallow and the tidal amplitude is also low at about 20-30 cm. Surface temperature had maximum values during premonsoon months and lower values during monsoon months - salinity showed a sharp decline during monsoon months. Dissolved oxygen values showed a decline during the monsoon season of 1990 but not during 1991 (Table-8. ).

Table-7. Environmental parameters at Station N-1

| Month | Temp °C | Salinity ‰ | Dis. $O_2$ ml/l |
|---|---|---|---|
| 1990 | | | |
| January | 28.08 | 28.83 | 3.15 |
| February | 29.0 | 26.72 | 3.23 |
| March | 29.96 | 26.57 | 2.66 |
| April | 30.58 | 25.57 | 2.68 |
| May | 31.2 | 21.9 | 2.89 |
| June | 29.08 | 3.19 | 3.61 |
| July | 28.83 | 3.96 | 0.64 |
| August | 29.0 | 5.33 | 3.50 |
| September | 28.83 | 17.92 | 3.22 |
| October | 30.85 | 29.30 | 5.24 |
| November | 30.33 | 18.50 | 3.35 |
| December | 29.15 | 29.25 | 3.28 |
| 1991 | | | |
| January | 29.7 | 31.63 | 3.28 |
| February | 30.30 | 29.94 | 3.30 |
| March | 30.4 | 24.52 | 3.63 |
| April | 31.0 | 20.25 | 4.42 |
| May | 31.73 | 22.63 | 2.96 |
| June | 28.3 | 2.63 | 3.48 |
| July | 27.75 | 2.05 | 3.79 |
| August | 28.13 | 1.52 | 3.71 |
| September | 28..13 | 21.02 | 2.69 |
| October | 28.5 | 19.05 | 3.31 |
| November | 28.5 | 9.77 | 5.15 |
| December | 27.5 | 30.88 | 3.04 |

Fig.10. Surface salinty, temperature and DO at station N-1 1990




Surface salinty, temperature and DO at station N-1 1991

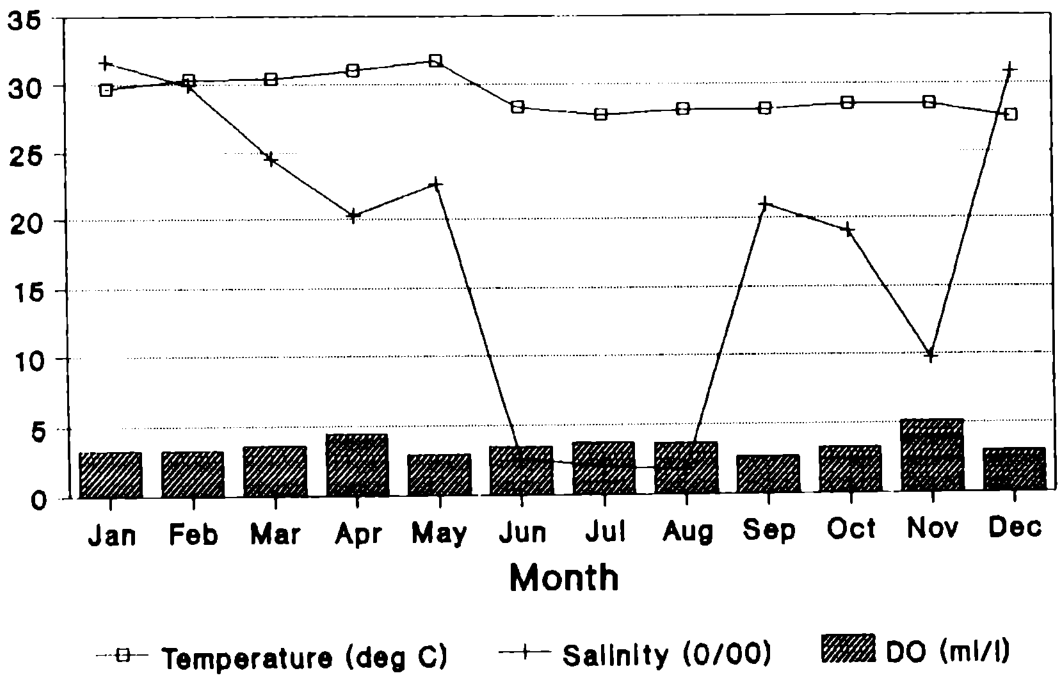
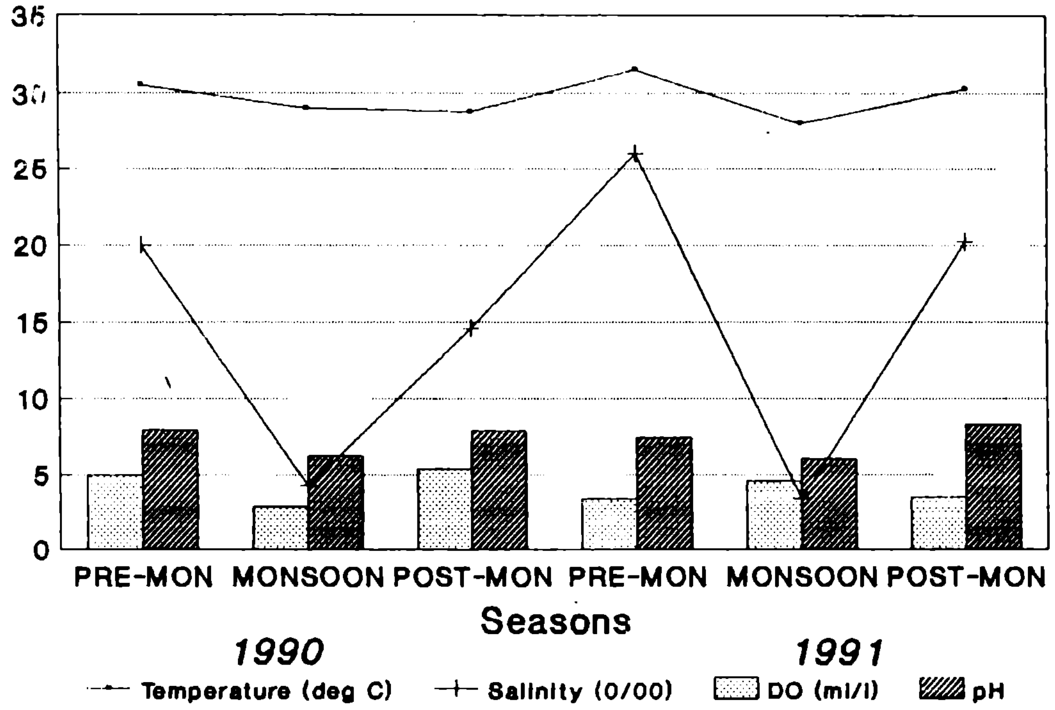


Table -8 . Environmental parameters at Station N-2

(Surface values)

| 1990 | T °C | Salinity (‰) | Dis. $O_2$ ml/l | pH | Nitrites | Nitrates | Ammonia | Phosphates µg/at/l | Silicates |
|---|---|---|---|---|---|---|---|---|---|
| Premonsoon | 30.5 | 20.7 | 5.0 | 7.97 | 0.39 | 2.12 | 67.50 | 13.77 | 5.00 |
| Monsoon | 29.0 | 4.3 | 2.9 | 6.26 | 0.72 | 2.30 | 41.10 | 35.60 | 63.00 |
| Postmonsoon | 28.8 | 14.6 | 5.4 | 7.89 | 0.36 | 1.66 | 56.60 | 23.60 | 10.1 |
| 1991 | | | | | | | | | |
| Premonsoon | 31.5 | 26.0 | 3.4 | 7.50 | 0.69 | 1.06 | 96.20 | 10.50 | 16.0 |
| Monsoon | 28.0 | 3.4 | 4.6 | 6.11 | 0.87 | 0.31 | 25.63 | 21.80 | 28.3 |
| Postmonsoon | 30.3 | 20.2 | 3.5 | 8.28 | 0.64 | 1.25 | 74.80 | 24.6 | 11.0 |

Fig.11. Environmental parameters at station N-2




Environmental parameters at station N-2

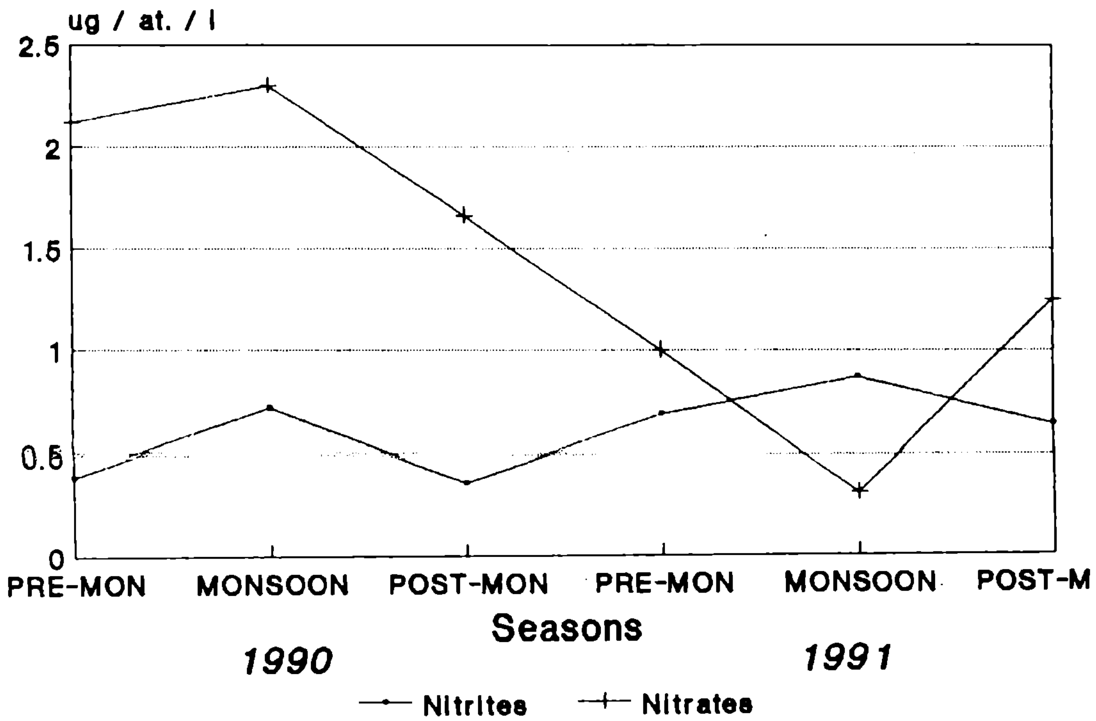
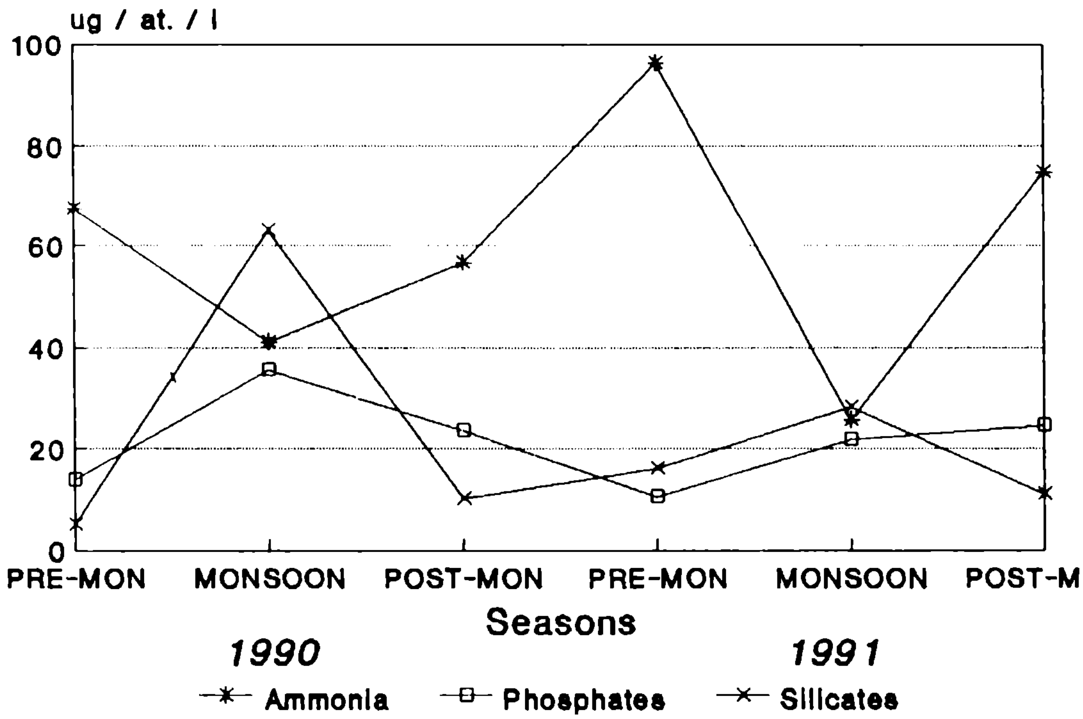


Fig.12. **Environmental parameters at station** N-2.



pH values showed a slight reduction during monsoon months. Among the nutrients the nitrite values showed increase during monsoon months. Nitrate values did not show a definite pattern. Ammonia values showed decline during monsoon months. Phosphates and silicate values showed increase during monsoon months (Figs. 11&12).

## Discussion

The major changes in hydrographic parameters in the mangrove waters occur during the monsoon period. The shallow canals and creeks are flooded with freshwater for over 3 months during this season. Reduction in salinity is the most conspicuous feature while surface temperature and $O_2$ show some fluctuations. Ramamirtham et al. (1986) observed that the surface temperature reached a peak in April and also that there was a gradual increase in temperature in the stations south of Cochin bar mouth. The minimum temperatures were recorded by him during monsoon months. He observed that cold and oxygen deficient water from the coastal areas are creeping into the estuary along the bottom, the influene of which is felt in the stations close to the Cochin harbour especially in the bottom waters. During non-monsoon months the vertical stratifications become negligible. However he observed that even during this period the southern stations near Vaikom had lower salinities compared to the ones near the bar mouth which indicated that the estuary is laterally non-homogenous type.

Sankaranarayanan and Qasim (1969) also pointed out the occurrence of stratification in the water column of the estuary during monsoon months. It is estimated that during the peak monsoon period the freshwater discharge from the southern rivers is over 1500 $m^3$/sec. During the non-monsoon months the tidal amplitude at Cochin is about 90 cm and the tides are of a mixed semi diurnal type. This amplitude becomes lower at about 30-60 cm at stations away from the bar mouth. Occasional storm tides are known to reach a height of 150-175 cm. The above factors are also responsible for fluctuations in nutrient levels and other hydrographic parameters in the estuary.

Gopalan (1986) while reviewing the nutrient levels in Cochin backwaters stated that nitrate-nitrogen has increased from a recorded low level of 0.3 $\mu$g at/l in 1965-66 to 4.0 $\mu$g at/l in 1975-79. He also found that phosphate phosphorous had increased from 0.36 $\mu$g at/l in 1965-66 to 0.85 $\mu$g at/l in 1974. Pillai (1990) observed that occasional high levels of ammonia in the estuarine system are due to discharge of effluents from fertilizer factories and also due to treated and untreated sewage disposal.

Excessive use of fertilizers such as N.P.K. in the agricultural fields, which are washed out during monsoon, is also considered as a cause for fluctuation in nutrient levels.

Pillai et al. (1983) have reported on the lowering of pH in the waters pumped out of paddy fields which became dry during a severe summer. Acidic waters leached out from such field lowers the pH in adjoining estuarine areas.

## AQUATIC PRIMARY PRODUCTION

The technique of using radio active $^{14}C$ for measuring organic production in the sea was first introduced by Steemen Nielsen (1952). Since then there has been a spate of contributions on this aspect world over. Nair (1970) who pioneered the use of this technique for Indian waters has given a comprehensive account on aspects of primary production and the methodologies adopted and standardised at the Institute from where the present study has been made.

In general, the contributions on the primary productivity of coastal waters and the oceans out weigh the studies on the same with respect to estuarine waters and mangrove areas.

As regards, Cochin backwaters, a detailed account on the organic production was given by Qasim et al. (1969). Aspects of photosynthetic pigments and primary production in the Pichavaram mangroves were studied by Krishnamurthy (1971) and Sundararaj and Krishnamurthy (1973). Nair et al. (1975) gave estimates of primary prodution in the Vembanad Lake. The productivity of the mangrove dominated estuaries in Goa was studied in Untawale et al. (1977).

In the present study an average piture is presented on the primary production and chlorophyll values based on the data collected from selected mangrove water stations.

Primary Production

During a preliminary survey carried out between 1976-78 at locations S-1 to S-4 in the southern part of the Cochin backwaters, the values ranged from 240 to 2150 mg C/m$^3$/day in the surface samples. The average values obtained during different seasons were as follows:

| | Mangrove locations | | | |
|---|---|---|---|---|
| | S-1 | S-2 | S-3 | S-4 |
| Pre-monsoon | 900 | 450 | 620 | 665 |
| Monsoon | 1370 | 510 | 610 | 370 |
| Post-monsoon | 805 | 560 | 630 | 455 |

(Production : mg C/m$^3$/day)

During 1980-82 surface primary production rates were estimated at Location S-5 which is also close to the location M-1, M-2 and M-3. The pooled average values for different months are as follows:

Gross Production

| | mgC/m$^3$/day | | mgC/m$^3$/day |
|---|---|---|---|
| January | 166.0 | July | 553.5 |
| February | 337.5 | August | 652.0 |
| March | 542.3 | September | 750.0 |
| April | 534.0 | October | 623.5 |
| May | 493.5 | November | 760.3 |
| June | 854.0 | December | 301.3 |

The above figures indicate that production rates are low during January-February, moderate during summer months March-May; reaches a peak during monsoon months and with minor fluctuations, decreases during the post monsoon months (Fig. 13). The production trend was similar to the one observed for Location S-1 and S-2 but not for locations S-3 and S-4 which are further south.

## Phytoplankton pigments

### At Location S-5

Surface chlorophyll a values were estimated in the mangrove waters at this location during 1988 to 1989. The average values of this pigment during the premonsoon, monsoon and postmonsoon season of 1988 were 2.54, 6.64, and 10.03 $mg/m^3$ respectively. During 1989, the values for the above seasons were 11.86, 13.37 and 10.3 $mg/m^3$ respectively. The pooled averages for the two years have been given in Table-6 and shown in Fig. 9, under the section on environmental parameters. It was observed that chlorophyll a values were higher during the monsoon season than the other periods.

### At Location N-1 and N-2

In the mangrove canals and creeks at the above stations still higher values of chlorophyll a was observed as follows:-

| | Chlorophyll a ($mg/m^3$) | | |
|---|---|---|---|
| | Premonsoon | Monsoon | Postmonsoon |
| N-1 | 5.2 | 17.3 | 21.5 |
| N-2 | 8.4 | 11.3 | 26.0 |

## Discussion

Gopinathan et al. (1982) have estimated the gross production in seasonal and perennial prawn culture fields as ranging from 650-3800 mg C/m$^3$/day. Nair et al. (1975) have estimated the total production in the Vembanad Lake (300 sq.km.) as 100,000 tonnes of Carbon/annum.

For the estuarine system of Cochin, Qasim (1970) estimated the gross production as ranging from 270-295g C/m$^2$/annum and an average production equal to 280g C/m$^2$/annum. The average net production was calculated as 124g C/m$^2$/annum.

Joseph and Pillai (1975) observed that freshwater species of phytoplankton become abundant in the estuary during monsoon with blooms and contribute to the productivity. According to Kumaran and Rao (1975) the fluctuation in phytoplankton abundance were largely due to 3 species of plankton such as *Skeletonema costatum*, *Nitzschia closterium* and *Coscinodiscus* spp.

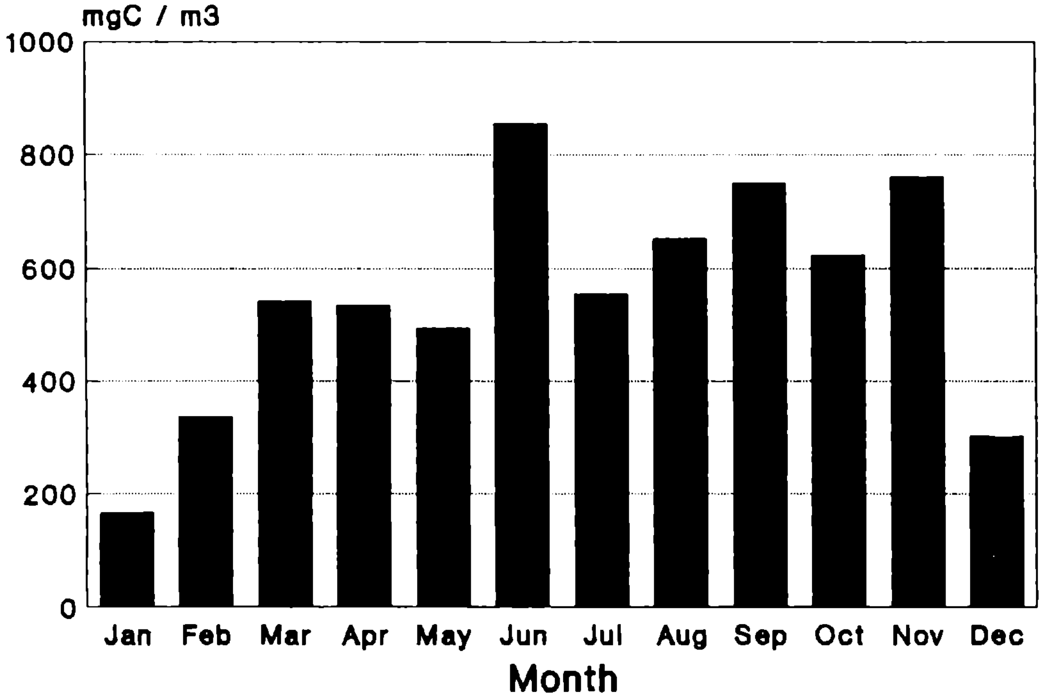
In the Mandovi and Zuari estuarine system during the monsoon, salinity was lowest in the estuary and stratification of water column was observed. Nutrients were high during monsoon and postmonsoon months (Qasim and Sen Gupta, 1981) compared to previous months. Average primary production was 0.58 and 0.43g C/m$^2$/day. The annual production was 166g C/m$^2$/day. Very low salinity does not sustain high phytoplankton population.

In the Vellar Coleroon estuaries, Krishnamurthy and Sundraraj (1973) found salinity dropping to 0 during north east monsoon. Higher nutrients were observed round the year. Chlorophyll values ranged from 2 to 21 $\mu$g/l. Gross and net production were reported as 0.59 and 0.38g $C/m^2$/day respectively.

In the Hooghly estuary on the east coast, where salinity is vertically homogenous, phosphate and nitrate values decrease towards the sea; whereas chlorophyll values showed increase. Average surface and column values were 1.0 $mg/m^3$ and 6.8 $mg/m^2$. Primary productivity ranged from 0.03 to 0.11 g $C/m^2$/day. The values were low due to high turbidity and lower photic zone. (Bhattathiri, 1962).

Phytoplankton production in the mangrove environment represents values generally found in seashore and estuarine environment. Untawale _et al._ (1977) found gross production in the mangrove waters of Goa as 2.24 g $C/m^2$/day and respiration was higher than plankton production. Krishnamurthy and Sundararaj (1973) reported an average production of 520 mg $C/m^3$/day for Pichavaram mangroves. The main contribution of mangroves to the environment is through litter fall and their degradation to detritus. Pant _et al._ (1980) found that while phytoplankton production is around 1-2 $gC/m^2$/day leaf litter contributes substantially to aquatic production.

Fig. 13. Surface primary production at station S-5
average monthly values



# 6. MANGROVE COMMUNITY STRUCTURE

## MANGROVE COMMUNITY STRUCTURE

The need for understanding and evaluating the parameters that determine the community structure of a mangrove forest is stressed by UNESCO as it would be helpful in planning management and conservations measures. Parameters such as relative density, relative dominance and relative frequency of each species impart the structure to the Community. A sumnation of these values for each species also gives an index of importance to the tree species.

Cintron and Novelli (1984) have suggested techniques that would yield much useful information for ecological studies and comparison of data from different parts of the World. Following the methods suggested by them, the còmponents of mangrove community were studied at location M-1, M-3, N-1 and N-2 and the results are presented in Table-9.

At "Mangalvanam" (M-1), the parameters were estimated at 2 plots, one close to the waterfront and one on the landward side. Here the predominant species is A. officinalis and this had the Importance value of 90.50 and 83.69 respectively at the two plots. R. mucronata plays a diminutive role in this location with a value of 9.50 to 16.31.

At location, M-3, the community structure is contributed by the codominance of R. mucronata, B. cylindrica and A. officinalis. Trees of Thespesia populnea have been included as they invariably occurred in the sampling plots.

Table-9. Importance value of mangroves at different locations

| Species | Relative values in % | | | |
|---|---|---|---|---|
| | Basal area | Density | Freqneucy | Importance Value |
| **Location M-1** | | | | |
| Plot (i) | | | | |
| *A. officinalis* | 92.62 | 90.00 | 88.89 | 90.50 |
| *R. mucronata* | 7.38 | 10.00 | 11.11 | 9.50 |
| Plot (ii) | | | | |
| *A. officinalis* | 95.81 | 80.00 | 75.18 | 83.69 |
| *R. mucronata* | 4.19 | 20.00 | 24.82 | 16.31 |
| **Location N-1** | | | | |
| *A. officinalis* | 85.00 | 85.70 | 88.00 | 86.20 |
| *E. agallocha* | 15.00 | 14.03 | 12.00 | 13.80 |
| **Location M-3** | | | | |
| *R. mucronata* | 33.91 | 37.35 | 30.00 | 33.75 |
| *B. cylindrica* | 34.91 | 25.28 | 30.00 | 30.06 |
| *A. officinalis* | 22.51 | 28.73 | 25.00 | 25.41 |
| *T. populnea* | 7.96 | 8.04 | 10.00 | 8.66 |
| *R. apiculata* | 0.71 | 0.60 | 5.00 | 2.10 |
| **Location N-2** | | | | |
| Plot (i) | | | | |
| *R. mucronata* | 23.87 | 17.50 | 23.07 | 21.48 |
| *B. cylindrica* | 41.85 | 48.50 | 46.15 | 45.50 |
| *B. gymnorrhiza* | 21.57 | 22.00 | 15.38 | 19.65 |
| *A. officinalis* | 8.47 | 7.00 | 7.69 | 7.72 |
| *E. agallocha* | 4.23 | 5.00 | 7.69 | 5.64 |
| Plot (ii) | | | | |
| *R. mucronata* | 61.50 | 26.95 | 37.50 | 41.98 |
| *B. cylindrica* | 14.13 | 52.17 | 37.50 | 34.60 |
| *A. officinalis* | 6.57 | 7.80 | 6.25 | 6.87 |
| *E. agallocha* | 3.02 | 4.30 | 6.25 | 4.52 |
| *T. populnea* | 14.78 | 8.60 | 12.50 | 11.96 |

At location, N-1 which is the recently sea accreted area with emergence of A. officinalis, the Importance value calculated for this species is 86.2 and for E. agallocha it is 13.8.

At location, N-2, two plots were surveyed In Plot (i) the vegetation is dominated by B. cylindrica with the Importance value index of 45.50 followed by R. mucronata (21.48), B. gymnorrhiza (19.65) and other woody species. In plot (ii) R. muronata (41.98) and B. cylindrica (34.60) have codominance over other species. Here also, Thespesia populnea has been included as this species occurred within the mangrove sampling plots.

Shannon index

Based on the Importance values obtained for different species at each location, the Shannon index was determined as follows:

| | | | |
|---|---|---|---|
| Location | M-1 | : | 0.136 - 0.193 |
| " | M-3 | : | 0.594 |
| " | N-1 | : | 0.175 |
| " | N-2 | : | 0.567-0.594 |

Complexity Index (Holdridge)

Complexity index of Holdridge et al. (1971) was worked out based on average community parameters obtained for 0.1 ha plots at different mangrove locations of the study area. These are presented in Table 10.

Table-10. Complexity Index of mangrove communities at selected sites/ locations.

(Trees having dbh greater than 2.5 cm)

| Location/Site | No. of species (s) | No. of trees (d) | Basal area($m^2$) (b) | Height (m) (h) | Complexity index |
|---|---|---|---|---|---|
| Location M-1 | | | | | |
| Site (i) | 2 | 200 | 2.1295 | 9.0 | 7.666 |
| Site (ii) | 2 | 100 | 3.8515 | 10.0 | 7.703 |
| Location M-3 | 5 | 174 | 1.6401 | 8.0 | 11.415 |
| Location N-1 | 2 | 350 | 0.6875 | 3.5 | 1.684 |
| Location N-2 | | | | | |
| Site (i) | 5 | 200 | 0.6682 | 7.0 | 4.677 |
| Site (ii) | 5 | 230 | 1.6634 | 7.0 | 13.390 |

## Discussion

Jagtap (1985) who studied the structure of mangrove communities in the major estuaries of Goa observed greater Importance value for *A. officinalis*, *R. mucronata* and *Sonneratia* spp. compared to other woody species. The average Shannon Index was 0.57. the average stand density observed by him was 461/ha in Mandovi and 857/ha along Galgibag. Mall *et al* (1985) observed in Andamans very high tree densities around 1800 stems/ha and basal area of about 6.95 $m^2$/0.1 ha. Because of the greater number of species, the IVI got distributed to more than 10 species.

In the Pichavaram mangroves Muniyandi and Natarajan (1983) obtained higher Importance values for A. marina, R. mucronata and R. apiculata compared to other species. About 7 woody species were accounted in the community. Stand densities ranged from 970 to 3000/ha.

In the present study, stand densities range from 1000 to 3500/ha. At location N-1 where the young Avicennia stands are involved, they have densely occupied, but owing to their smaller diameter (3-5 cm) their basal area contribution is not much. Or the other hand, older Avicennia stands at M-1 contribute greater basal area of 3.85 $m^2$/0.1ha.

In a well developed riverine mangrove forest in Costa Rica, basal area of 96.4 $m^2$/ha was observed by Pool et al. (1977). He also observed that riverine and basin forest types had taller canopies as compared to scrub, fringe and overwash forest types. Canopy heights upto 55 m were reported by Soekardjo and Kartawinata (1979).

The present study area is highly exposed to human induced stresses such as cutting of canopy branches for fuel and other uses regularly. Yet in certain undisturbed areas such as M-1, M-3, N-2 and W-2 their present day structure is comparatively good. The complexity index of these locations reflect this.

## Mangrove Litter Production

Mangrove litter production plays an important role in the export of both particulate and dissolved organic matter to the adjacent marine ecosystem. The litter fall includes both vegetative and reproductive parts and these form a part of the forest net primary production and which gets accumulated on the forest floor, then decomposed and exported to the aquatic environment where it supports detrial based food chains.

Litter production estimates were made from the mangrove to location M-3 by placing traps of 0.25 $m^2$ frame below the stands of *Avicennia officinalis*. The average production rates obtained during 1990 are given in Table-11 and Fig. 14.

Table-11. Litter production by *A. officinalis* ($g/m^2$) dry wt.

| Month | Leaf | Twigs | Flower | Fruit | Misc. | Total |
|---|---|---|---|---|---|---|
| J | 32.3 | 4.2 | – | – | 4.8 | 41.3 |
| F | 39.2 | 5.5 | – | – | 4.4 | 49.1 |
| M | 42.2 | 5.2 | – | – | 3.5 | 50.9 |
| A | 52.4 | 9.8 | 15.5 | – | 6.5 | 84.2 |
| M | 75.3 | 12.5 | 20.2 | – | 12.3 | 120.3 |
| J | 62.5 | 11.3 | 12.5 | 20.2 | 5.7 | 112.2 |
| J | 28.2 | 10.4 | 6.4 | 38.6 | 5.9 | 89.5 |
| A | 22.4 | 5.6 | 5.5 | 12.4 | 4.6 | 50.5 |
| S | 27.8 | 3.7 | - | - | 3.2 | 34.7 |
| O | 30.4 | 4.5 | - | - | 4.5 | 39.4 |
| N | 29.2 | 4.0 | - | - | 2.8 | 36.0 |
| D | 24.5 | 3.4 | - | - | 3.5 | 31.4 |
| TOTAL | 466.4 | 80.1 | 60.1 | 71.2 | 61.7 | 739.5 |

Annual total litter fall was estimated as 739.5 gm/$m^2$ dry weight. Out of which leaf litter alone contributed 466.4 g/$m^2$ (dw) and this forms about 63% of the total litter. Among the other components, fruit fall was observed during the months June to August and contributed 71.2 g/$m^2$ (dw) forming 9.63%. Broken twigs and branches contributed 10.83%. Flowers 8.13% and miscellaneous debris, 8.34%. The average rate of production of leaf litter was estimated as 1.278 g/day/$m^2$ (dw) and total litter as 2.026 g/$m^2$/day (dw).

Similar observations made on litter fall under the canopies of R. mucronata at Location N-2 indicated annual leaf litter production as 329.4 g (dw)/$m^2$; fruit and propagules at 191.6 g, other components 282.5 g and the total litter fall as 803.5 g (all in dry wt/$m^2$).

At location N 1 dominatted by young stands of A. officinalis, the rate of accumulated litter on the forest floor was estimated as 71.62g/$m^2$/month (dw) during premonsoon months March to May.

Fig. 14 shows monthwise total litter production of A. officinalis and also its components. The production is maximum during the months May to July contributed by increased litter fall by leafs, flowers and fruits. The production trend also reflects the phenology of this species. The flowering season for this species is from April to June and fruiting from June to August.

The peak period of flowering and fruiting for other species in this region was observed as follows:

| | Flowering | Fruiting |
|---|---|---|
| A. ilicifolius | March-April | May-June |
| B. cylindrica | November-January | April-May |
| B. gymnorrhiza | November-December | March-April |
| R. mucronata | December-March | June–August |
| E. agallocha | March-April | May-June |

It was also observed that strong winds accompanying premonsoon showers in May and subsequently in the monsoon months influene the litter fall.

Discussion

Blasco (1986) has given estimates of litter fall from different regions collected from various sources. Leaf litter alone from R. mangle in Florida ranges from 4.75 - 10.70 (t/ha/annum), A. germinans 2.85 - 4.85(t/ha/a). In Australia, total litter fall for different species ranges from 5.80 to 9.67 (t/ha/a) from A. marina; 8.69 to 10.91 (t/ha/a) for Rhizophora spp. 7.99 to 9.96 (t/ha/a) for Bruguiera spp. Christen-sen (1978) estimated the net primary production of R. apiculata in Thailand as 27 t/ha/annum, of which leaf litter contributes 6.70 t. Blasco (1986) stated that the ratio between leaf production and other components vary from place to place and also from one type of mangrove to another. In a dense mangrove forest in Asia a biomass of 100-200 t of dry matter/ha was estimated as standing stock above ground (Christensen, 1978).

The importance of mangrove litterfall in the detritus based food chains was first indicated by Golley et al. (1962); Odum (1971) and Heald (1971).

Macintosh (1982) while reviewing the aspects related to litter production stated that it is reasonable to expect that 50% of the total leaf fall is the annual net export to the coastal water. He observed that the process of litter decomposition is a complex one in which insects, crabs, fungi and bacteria are involved. The leaf material of Avicennia and Rhizophora have been observed to decompose fully within 10 and 18 weeks respectively and contribute to the detritus production in the aquatic environment.

Recently Gong and Ong (1990) studied the biomass production in a managed mangrove forest in Malaysia and calcuated that annually the biomass and nutrients from leaf litter exported out are 3.9 and 0.1 t/ha respectively.

Based on the present study on litter production it is inferred that about 4 tonnes/ha of litter production is the annual export of this material to the coastal waters.

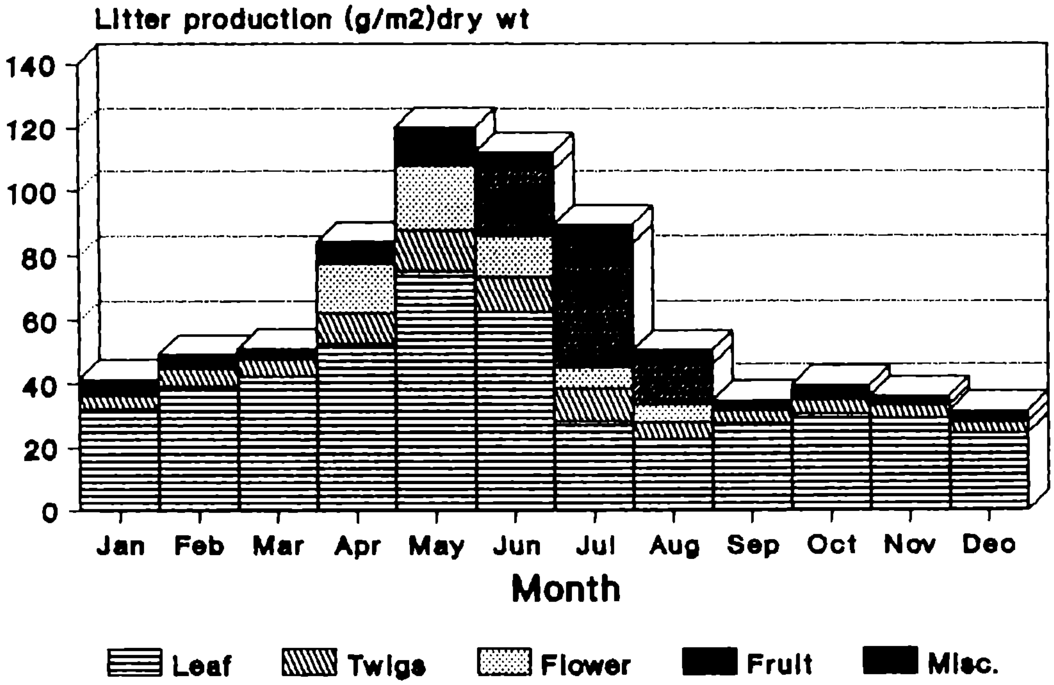



**Fig. 14.** Litter production of A. officinalis

# 7. SIGNIFICANCE OF MANGROVES IN FISHERIES

## SIGNIFICANCE OF MANGROVE IN FISHERIES

It is well recognised that a number of species of fishes and prawns ingress into the mangrove water bodies which serve as feeding or nursery sites. Studies carried out in Florida (Odum and Heald, 1972) Malaysia (Ong, 1978); India (Jayaseelan and Krishnamurthy, 1980) and New Gunea (Collette and Trott, 1980) have shown that more than 100 speies fishes and prawns enter the mangrove fringed estuaries, canals and creeks during the part of their life cycle. The significance of the mangrove ecosystem in the recruitment of fry and larvae of finfishes and crustaceans along the east coast including Sunderbans has been critically reviewed by Silas (1987).

Some observations made in the study area are given here. Among the commercially important marine prawns, the occurrence of early post larvae and juveniles of seven species in the estuaries along the southwest coast of India is known. These are, *Penaeus indicus*, *P. monodon*, *P. semisulcatus*, *P. merguiensis*, *Metapenaeus dobsoni*, *M. monoceros* and *M. affinis*. Among these, the larvae and juveniles of *P. indicus* and *M. dobsoni* were observed to occur in the canals and creeks of mangrove location N-1, N-2, M-3 (north of Cochin barmouth) and location S-3 and S-4 (South of Cochin, near Perumbalam).

Although postlarvae and juveniles of *P. indicus* was encountered throughout the year at the above locations, their peak period of abundance was April in the northern stations and December-January in the southern stations.

As regards, M. dobsoni, this species also occurs throughout the year, but their peak period of abundance was during September-October in all the stations. The postlarvae of P. monodon was abundant only at Puduveyppu during August -September and scarce in other centres. M. monoceros also occurred only in small numbers.

The size of P. indicus was 7-60 mm and that of M. dobsoni was 6-30 mm. In both species the postlarvae have dominant mode at 11-20 mm size.

The average number of total postlarvae collected range from 700-2000 nos/$m^3$ of water.

Among the fry and fingerlings the species of less commercial importance that commonly occur in the creeks were Ambassis dayi, A. commersoni, Haplocheilus melastigma, Therpon puta, T. jarbua; Tetradon spp., gobioid fishes and cat fishes.

The fingerlings of commercially important species was mostly mullets such as Mugil cephalus, Liza parsia, L. macrolepis, Chanos chanos, Etroplus suratensis and E. maculutus.

At location N-2, Chanos fry occur in good numbers during May-June and mullet M. cephalus during June to August and other species of mullets throughout the year. In 'hapa' type collections the number caught per hour of operation ranges from 25-200 for the above species during peak periods.

The life history and migratory habits fin fishes and crustaceans are taken advantage of in local sustenance capture fisheries within the estuary and for traditional farming practices such "Chemmenkettu" in Kerala.

The extent of mangroves, their contribution to detrital food chain, larval ingress of commercially important species into the mangrove/estuarine waters, their nursery phase, their exploitation within the estuarine system, their return to the sea and contribution to coastal fish production are subjects which are interlinked in the complex food web and pathways of energy flow. It is felt necessary to examine some available information with respect to Kerala State. There are about 30 estuaries and backwaters in the State of which the Vembanad lake with a spread of 300 $KM^2$ is the largest.

80% of an active fisherman population of about 43,000 are fully dependent on the backwaters for their livelihood. It is observed that these fisherman have been employing fixed gears such as stake nets, Chinese dipnets and 'Madavala' mainly to capture the species which come along with the tides. The estuarine area is visited by over 100 species of commercially important fishes, belonging to 45 families such as Clupeidae, Engraulidae, Gerridae and Leiognathidae.

Pearl spot, milk fish and mullets form an economically important group in the landings. Among the marine prawns, juveniles of Metapenaeus dobsoni, M. monoceros and Penaeus indicus dominate the catches of the backwater fisheries. Penaeus monodon and P. semisulcatus are relatively low in the catches. The giant freshwater prawn Macrobrachium rosenbergii is caught mostly in the upper reaches of the backwater. Among the crabs, Sesarma spp. and Scylla serrata are encountered in the catches.

Increased fishing pressure in the backwaters

Large scale removal of postlarvae &juvenile population by gears such as stake nets and dipnets should be considered as destructive type of fishing which would ultimately affect the coastal fisheries which are dependent on them.

In recent years the number of units of Chinese dip nets have increased from 1916 (in 1984) to 4815 in 1990. Similarly the numbers of stake nets have increased from 9196 in 1984 to 12,909 in 1990. While these figures are for the whole state, the number of units of chinese dipnets and stake nets operated in the Ernakulam district are 3577 and 6664 respectively (Source : Department of Fisheries, Kerala).

The annual landings from all types of brackishwater fisheries has increased from 14634 tonnes in 1984 to 21,235 tonnes in 1989 out of which the prawn landings are over 40% (in 1989). Among the prawn species, M. dobsoni accounts for the bulk of the catches (79%). The catches of this species has shown a decline in the inshore trawl catches from 31.9 kg/boat (1985) to 16.3 kg/boat in 1988. Increased exploitation of this species in the estuarine areas by the fixed gears such as stake nets may be one of the causes for the decline in the inshore catches.

## Discussion

It is understood there is a system of issuing licences to the operators of stakenets and chinese nets at a nominal fee. However, a large number of these nets have been erected without any licence or control. Eventhough the operation of stake nets during high tide is prohibited by law, these nets are indiscriminately used during this tide. Further the mesh size used in 5 mm which is detrimental to the population of larvae and juvenile entering the backwater.

It is essential that this destructive type of fishing is regulated so as to sustain production from both estuarine and coastal areas. It is appropriate here to draw attention to important observattions made by Silas (1987) on the mangrove dependent fisheries in India. Referring to the mass tagging experiments conducted by CMFRI on the juveniles of *P. indicus*, he reported that this species tagged and released off Cochin have been recovered in the Gulf of Mannar, near Tuticorin after 62 days and after traversing a distance of about 380 km. This showed that this species as well as other estuarine or mangrove based juvenile stocks are capable of migrating to long distances and contributing to the fishery of a totally different region from where they originated.

Another observations made by him was with regard to the extent of mangroves along the coasts of maritime States on the east coast and its relationship to the total fish production, to the penaeid prawn catches from the inshore areas, penaeid landings from large trawlers and also the quantity of fish discarded by them. It was shown that capture fisheries in this region are dependent largely on the fry and juveniles of fishes and prawns recruited from mangrove areas of Orissa and West Bengal.

The once mangrove dominated low lying areas of Kerala have been converted in the past as seasonal (Pokkali) prawn culture fields and perennial prawn filtration areas. The area under this practice has increased from 4000 ha in 1960 to 13,000 ha at present showing a threefold increase. In the Ernakulam dt. the area at present is around 10,600 ha. Inestimable quantities of juvenile prawns and fishes are trapped and fished under this system. Considering the draw backs in this practice such as low production rates, this system of trapping and holding juvenile prawns needs evaluation and alternate methods of utilizing these fields for scientiic farming through hatchery technology for seed production should be thought of.

With the shift in priorities towards large scale brackishwater farming for finfishes and crustaceans, maritime States are vying with each other in leasing out large areas for brackishwater aquaculture and naturally this would infringe onmangrove areas which are already threatened with depletion and degradation.

In a critical study on the fish and prawn seed resources in the Sunderban mangrove areas, Silas (1987) has catalogued the seed resources of many commercially important species of prawns and fishes and their seasons of abundance. With the intensification of farming of prawns such as P. monodon in large systems known as 'Bheries' (average extent 80.5 ha) there is a tremendous increase in the collection and trade of prawn seeds especially for P. monodon. It has been observed that for every Kg. of live prawn seed collected, there is a mortality of about 10 Kg. of fry and larvae of finfish and other prawn species. This would also come to conflict with wild stocking of Bheries. Silas (1987) suggested that hatchery production of seeds is the only answer to any expansion in brackishwater aquaculture.

# 8. CONSERVATION AND MANAGEMENT

Threats to the mangrove ecosystem and suggestions for rehabilitation/ conservation

In general the mangrove areas in India have undergone a long period intensive and continuous exploitation. What we find now are only left overs. The situattion in Kerala's backwaters is unique in the sense that almost all the area once occupied by mangroves have been converted for various purposes. According to Vannucci (1984) 61 $km^2$ of 'Kari' lands with dark peaty soil having high proportion of carbonaceous wood represent areas which were once a dense mangrove forest. Similarly in the middle and northern sectors of the backwaters about 60 $km^2$ of mangrove areas were converted as paddy-cum-prawn culture fields.

According to Gopalan et. al (1987) man-made changes and alterations such as bunding and reclamation for agriculture, aquaculture, harbour and urban development and other purposes have resulted in an alarming rate of shrinkage of backwaters of Kerala. The statistics provided by them shows that between 1834 and 1984 about 23,104 ha of the Vembanad lake estuarine system have been reclaimed and converted for various uses.

In the present study area around Cochin, reclamation work for development activities as listed below has affected the extent of mangrove areas also.

| Period | Area reclaimed (ha) | Purpose |
|---|---|---|
| 1920-36 | 364.37 | Creating of Willingdon Island for harbour development. |
| 1978 | 10.78 | Fisheries Harbour |
| 1981-85 | 141.70 | Vallarpadam-Ramanthuruthu Island complex for Port Development (Mangrove Location - M-3). |
| " | 141.70 | Southern extension to Willingdon island(Port Development)(Mangrove) Location - S). |
| " | 23.91 | Urban Development - Marine Drive Perfect of Greater Cochin Development Authority. |
| " | 11.73 | For Cochin Shipyard, Oil Tanker berth and for other uses. |

Source : Gopalan et al., 1987

Various forms of threat to the mangrove areas is continuing as a result of population pressure and growing need for land for housing, urban and industrial development. Around Cochin city more and more of wet lands are being converted by filling earth for developing housing and industrial estates.

In the sea accreted area at Puduveyppu (Mangrove location N-2), encroachment on mangrove habitats is taking place by the local inhabitants who fill up the swamps with beach sand to put up their houses. There is also regular poaching of wood from the resurgent Avicennia formation at N-1 and the multispecies stands at N-2.

The estuarine areas around Cochin are becoming increasingly polluted with various type of pollutants such as sewage disposal; treated and untreated effluents from factories; pesticides and fertilizers from agricultural fields, oil pollution from ships, fishing boats and oil tankers.

Pillai (1990) indicated that the quantity of effluents discharged from the factories in Eloor industrial area and Ambalamugal put together is around 200 million litres per day. The waste water from the Cochin city and organic wastes form an additional land. He has reported on the instances of fish mortality due to lowering of pH in Eloor area, and the very high levels of ammonia in the Ambalamugal area.

It is reported that about 250 tonnes of pesticides are used annually in the Kuttanad rice fields adjacent to the present study area. The pesticides leached out from the rice fields are reported to be traced in the tissues of mussels, cat fish and prawns as residues (Pillai, 1990). He also drawn attention to the high consumption fertilisers (N.P.K.) in the Kerala State to the tune of 1.4 lakh t/annum for agricultural purposes and the probability of 50% of this quantity entering the aquatic environment.

Construction of a salt water barriage at Thannermukkom (Near Mangrove Location W-2) and flood control spillway at Thottapally have brought about changes in abiotic and biotic factors of the estuary. These are examples of man made changes that pose a threat to the mangrove ecosystem and dependent fauna.

Suggestions for conservation of mangrove loations:

In the light of various threats to the mangrove vegetation and dependent aquatic fauna the following of measures are suggested for rehabilitation and conservation of mangrove habitats.

1. Improvements to 'Protected' areas

a) The mangrove swamp of Location (M-1) "Mangalvanam" is already declared as a "protected" forest and a bird sanctuary. The areas adjacent to the core area of about 3.44 ha is in the possession of Railways as goods shed and yard. This additional area has to be transferred to the State forest department. The whole area may be fenced to prevent poachers from cutting wood and to prevent people from scarring away the aquatic birds nesting in the area. The parking of oil tanker trucks in the area should be shifted to someother area. Once the additional area of about 5.0 ha becomes available, a mangrove research centre could be set up there for scientific studies on the flora and fauna. A rreference collection museum is also suggested. For bird watching and monitoring their behaviour, an observation tower can be set up. Seedlings of Avicennia and other species could be raised on a large scale and distributed to various departments and agencies for taking up mangrove afforestation programmes.

b) At Kumarakom (W-2) which is also declared as a bird sanctuary and 'protected' area, experiments should be undertaken to raise seedlings of vulnerable and rare species such as Heritiera littoralis, Kandelia candel and Sonneratia caseolaris and planted in other vacant intertidal areas in the vicinity as a measure of rehabilitation. In fact the area can be developed as a 'Mangrove Botanical Garden' so that representative of all species can be grown, protected and observed for scientific studies. An observation tower for bird watching may be constructed here.

2. Creating a Mangrove Habitat Preserve

The sea accreted area (N-1) extending from the Cochin bar mouth to Puduveyppu is now dominated by Avicennia officinalis in the process of seral succession. This whole area should be declared as a 'Mangrove Habitat Preserve' and earmaked for total conservation and scientific studies. This area is bordered with a tidal canal on its eastern side. The sides of this canal can be planted with Rhizophora seedlings which are available in plenty at Puduveyppu during July-September. Behind the rows of Rhizophoras, seedlings of Bruguiera cylindrica could also be planted. This species thrives very well at Puduveyppu even under stress conditions.

Considering various threats to mangrove ecosystems and population density in the Vypeen island, there is imperrative need for totally protecting this area because it is uninhabited at present. This block of about 300 ha can be developed as one of the best mangrove habitat preserve similar to the "mangrove parks" developed in Australia.

The Puduveyppu area (N-2) is now having human settlements around with fresh encroachment on multispecies mangrove formations. This area could be developed as a bufferzone with regulated use of the area without detriment to the mangrove vegetation.

3. Other suggestions:

a) Construction of granite embankment on the margins of islands and canals in the estuary should be discouraged and mangrove species such as *Rhizophora mucronata* and *Avicennia officialis* should be planted through a planned social forestry programme involving voluntary agencies.

b) Urban development authorities such as the Greater Cochin Development Authority and the Cochin Corporation should be educated on the significance of mangroves while they plan for any development activity that would involve wet lands or mangroves.

c) The Cochin Port Trust Authorities should be discouraged from taking up further reclamation work in the backwaters, which is already shrinking. The patch of mangroves that is rapidly coming up at the southern portion of Willingdon Island should be protected and saved.

d) There are many patches of waste land near locations W-1(Kannamali) and N-2 (Puduveyppu). A massive afforestation programme can be taken up with the involvement of the Department of Environment, Government of India, the State Forest Department and voluntary organisations.

## 4. Management strategies

The mangrove ecosystem should be viewed as an important component of the coastal zone, where development activities come into conflict with conservation measures. Silas (1987a) outlined a number of management strategies for the country as a whole. For the Cochin estuarine system the following management measures could be considered:

i) Planned surveys and mapping of all mangrove areas to understand the extent of mangroves, areas degraded and the potential areas for development of aquaculture;

ii) Evaluation of mangrove areas as a nursery ground, environment impact assessment vis-vis development activities. Stoppage of destructive type of fishing such as the use of stake nets.

iii) Determining the percentage of area to be sacrificed for a aquaculture develpment; criteria for selection of sites and precautions to be taken with respect to the mangrove vegetation.

iv) Determination of optimum size for pond aquaculture depending on soil conditions tidal amplitude and other factors.

v) Problems relating to acid sulphate soils in the Pokkali fields of Cochin estuarine system and their management.

vi) Promoting research on various aspects of mangrove biology and management.

vii) Adoption of semi-intensive farming and hatchery systems for reducing pressure on mangroves.

viii) Economic evaluation and cost benefit analysis of subsistance activities such as sea farrming net cage and pen culture and other types which will give better economic returns without affecting the environment.

ix) Indepth studies regarding the linkages between mangrove - nursery - coastal fish/prawn production; stoppage of destructive type of fishing that affect recruitment of stock from nursery ground to coastal area.

x) The importance of mangrove biosphere - reserves - the role of sanctuaries, parks and reserves in the preservation of plant and animal genetic resources.

# 9. GENERAL DISCUSSION

# GENERAL DISCUSSION AND INFERENCES

The Cochin estuarine system compising the Cochin backwaters and the Vembanad lake system is one of the largest wet land ecosystem in South India. This area comprising about 300 sq.km. had extensive mangrove formations in the past and most of them, about 120 sq.km. have been sacrified for agriculture, coconut plantation and paddy-cum-shrimp culture. However in recent years pockets of residual mangrove patches, areas of regeneration and resurgence of vegetation in relcaimed areas and sea accreted land were observed. The candidate took up a study of these to understand their structure, dynamism and ecological factors. Based the observations made, data presented and discussed the following inferences are made:

## 1. Inventory of the mangrove areas:

While isolated pockets of mangroves and vestiges of vegetation are scattered throughout the system, the candidate has presented here 16 mangrove areas which are distributed on the northern and southern side of the Cochin harbour. Detailed descriptions about the extent and status of the mangroves have been provided.

The locations, viz., Mangalvanam (M-1) and Kumarakom (W-2) have remained as "protected" areas and hence the mangrove stands are in a state of preservation. Two areas N-1 and N-2 near at Vypeen and Pudu-veyppu are sea accreted area and at N-1 there is an extensive formation of Avicennia officinalis. At Puduveyppu there are stands of different species. At three locations, viz, harbour islands, Vallarpadam, and south of Willingdon island the formations have come up on reclaimed areas. In other location mangroves are residual populations or regenerating ones. The Vypeen-Puduveyppu formation extends to about 300 ha and is the largest in the estuarine system.

2. Species composition:

53 species belonging to 16 families are recognised as mangroves (Champan, 1970). The candidate observed 16 species as commonly occurring in the study area. Their locationwise description has been given in Table-1. Species such as A. officinalis, R. mucronata, A. ilicifolius had a high frequency of occurrence. Next in order came Clerodendrum inerme, E. agallocha, Bruguiera cylindrica and Acrostichum aureum. Three species of Bruguiera viz. B. gymnorrhiza, B. cylindrica and B. sexangula from one location N-2 is recorded here. The occurrence of Rhizophora apiculata, Sonneratia caseolaris, Kandelia candel and Heritiera littoralis although in small numbers is reported here. Species such as Ceriops tagal, Lumnitzera racemosa, Rhizophora stylosa and Xylocarpus granatum which occur in the east coast and Andamans are conspicuous by their absence. Out of the areas studied, location N-2 and W-2 are rich in species.

3. Zonation

The tidal amplitude at Cochin harbour is 90 cm and gets reduced to a range of 30-60 cm in locations in most of the mangrove areas. The edge of the water is usually occupied by species such as A. ilicifolius

A. officinalis or R. mucronata behind which a mixed zone of 4-5 species occur. Diagrammatic of profile of vegetation at selected locations are given in Figs. 4 to 6.

4. Succession

The vast stretch of recently sea accreted mud flat at Vypeen (N-1) was colonised in early 1980's by marsh grasses, Panicum spp., Cyperus spp and Acanthus ilicifolius. These have been now succeeded by A. officinalis predominantly. At Narakkal and Perumbalam islands (N-5 and S-4) areas cleared of mangroves are colonised by Acrostichum aureum.

5. Morphological characters

Morphological characters of each species may vary from region to region depending on climatic and edaphic factors (Vannucci, 1989). Tall trees exceeding 100 feet and girth over 3 feet were reported by Watson (1928) in Malaysian Forest. In the present study maximum height of 15 m was observed at one location in the case of an old Rhizophora mucronata tree. Detailed descriptions of common taxa have been given with illustrations.

6. Climatic parameters

An average picture of rainfall and temperature during differrent months at Cochin has been presented. The area comes under the tropical rainfall zone. the mean annual rainfall is over 300 cm. The thermal amplitude is below 6°C between the coldest and warmest months. The ratio between mean rainfall and potential evaportranspiration is greater than 0.75. This suggest that the area is favourable to mangrove communities.

7. Edaphic parameters

Soil texture in mangrove locations showed admixture of Sand-silt-clay fractions. In general sand fraction dominated the soils with proportion of silt and clay varying. Variations were also observed within a location. Soil pH ranged from 6.94 to 7.92; conductivity ranged from 5.6 to 15.5 (mm hos/cm); CEC ranged from 17.63 to 21.36; organic carbon had high percentage ranging from 1.8 to 2.45. The available nutrients and exchangeable cat-ions suggest a fertile status to the soils.

8. Environmental parameters

Monthly mean values of surface temperature, salinity and dissolved oxygen for two years have been given for Location N-1 (Table-7). This would show that the temperature amplitude is around 4°C. Salinity ranged frrom 1.52 to 31.63 in 1991 and oxygen content varying from 0.64 to 5.24 ml/l.

An average picture of seasonal variations in hydrographic parameters and nutrients has been presented for Locations N-2 and S-5. these are intended show the variations observed from station to station and during the seasons. During the monsoon months drastic reduction salinity, slight reduction in temperature and pH have been observed. Nitrites and phosphates showed increase during monsoon season at N-2 where as this showed a drop at location S-5. The level of ammonia also showed reduction during monsoon months.

Possible inferences are: variations in these parameters are related to the general features in the estuary which is turn in influencedby rainfall, river run off, effect of coastal upwelling and thermal stratification during monsoon months. The fluctuations in nutrients and high values of Ammonia (25.63 to 96.20 $\mu$g at/l) are attributed to discharge of effluents and sewage into the estuary and also to the large scale use of fertilizers in the agriculture opeations. (Gopalan et al. 1987; Sankaranarayanan and Qasim, 1969).

9. Aquatic Primary Production

Estimates of gross primary production at location S-5 showed that this fluctuated between 166.0 mgC/m$^3$/day in January to 854.0 mgC/m$^3$/day in June. At Location S-1 and S-2 production showed higher values compared to premonsoon season (Range 450 to 1370 mgC/m$^3$/day). The overall trend in production showed that the values are moderate to high, but falls within the range of gross production estimated by Qasim (1970) as 270-295 gC/m$^2$/annum. The mangrove canals and creeks are shallow (1.5-2.0 m) and turbid and generally production rates are low (Vannucci, 1989). The production rates from different regions have been given and discussed in the relevant chapter.

10. Community structure

Community parameters of mangrove trees were estimated at locations M1-M3, N1 and N2. The architecture is simple at M1 with trees of A. officinalis dominating. Similarly at location N-1 also the recent stands of this species are dominating. The Importance Value Index obtained for this species at these locations range from 83.69 to 90.50 At location N-2, B. cylindrica, R. mucronata and B. gymnorrhiza had IVI as 45.50, 21.48 and 19.65 respectively in one plot. The indices for other plots and areas are given in table-9. The complexity indices for different locations ranged from 1.684 to 13.390. Shannon Index for species diversity ranged from 0.136 to 0.594. These indices have been compared with those obtained elsewhere and discussed.

11. Mangrove litter production:

Monthly litter production rates of A. officinalis is presented in Table-11. The total litter production was estimated as 739.5 $g/m^2$ (dw). Leaf litter formed 63.06%. The net export of litter out of the system has been indicated as 4t/ha/annum. Litter fall estimates have been compared and presented.

12. Significance of mangroves and fisheries

The occurrence and abundance of postlarvae and juveniles of commercially important species of prawns such as Penaeus indicus and Metapenaeus dobsoni in the mangrove waters of the study area is highlighted. Both species occur throughout the year but their peak period of abundance differ. The average number of postlarvae of all species collected range from 700-2000/$m^3$ of water. The sizes of postlarvae range from 7.60 mm for P. indicus and 6-30 mm for M. dobsoni. The increased fishing pressure in these species is drawn attention to. The operation of stake nets has increased from 9196 in 198 to 12909 in 1990 in the Kerala's backwaters. M. dobsoni accounts for the bulk of the catches.

The increase in the acreage of traditional farming areas for shrimp has increased from 4000 to 13000 ha in Kerala State. The effect of the destructive type of fishing for M. dobsoni in the estuary is discussed in the light of linkages with the coastal production.

13. Threats to the mangrove ecosystem

Various forms of threat to the mangrove ecosystem has been indicated. These include anthropagenic pressure, poaching of wood from the system, encroachment on the forest, large scale reclamation in the estuarine areas, filling up of marshy areas for housing and other purposes, construction of salt water barrage, industrial pollution that affects the water quality, use of pesticides and fertilizers in agricultural fields which find their way into the system.

14. Suggestions for conservation

Based on the present study, the candidate has given some suggestions toconserve the existing protected mangrove areas, the need for creating mangrove preserves, afforestation programmes and the need for integrated management measures.

# S U M M A R Y

The thesis embodies the results of investigations carried out by the candidate on aspects of the mangrove ecosystem in the Cochin estuarine system. The mangroves characterise a unique ecosystem endowed with great biological wealth and species richness. It is a life support system and an important componentof the coastal zone. Instead of realizing its important role in nature, mangroves in many parts of our coastline have been indiscriminately exploited for immediate economic gains. In the Cochin estuarine system mangroves have undergone total conversion for agriculture, traditional shrimp farrming and reclamation for various development activities.

However, surveys carried out by the candidate reveals that there are large patches of resurgence of mangroves in sea accreted areas, reclaimed land and in isolated protected areas. The present study focuses light on the extent of such mangrove areas, the structure and dynamics of the vegetation and related ecological aspects.

The Introductory chapter deal with information highlighting the importance of the ecosystem, and gives a resume of reported literature relevant to the present study.

The material and data collected and methodologies used are out lined in a separate chapter.

Sixteen locations were studied which included areas of mangrove resurgence, areas of regeneration, residual areas and protected areas. Detailed description of these locations have been given with an inventory

of species, zonation and other parameters.

Sixteen mangrove species were found to occur in the study area. Their distribution pattern in differrent localities has been analysed and presented. Species such as Avicennia officinalis, Rhizophora mucronata, Bruguiera cylindrica and Acanthus ilicifolius have been observed to occur in almost all the localities. Species such as R. apiculata, Sonneratia caseolaris, Kandelia candel were observed in small number as relies.

Realizing that morphological characters vary in different regions according to local climatic and edaphic factors, detailed descriptions of the important taxa have been presented in the next chapter.

The present study area falls under the tropical rainfall zone. The influence of the monsoon on climatic, edaphic and other environmental parameters and their relevance to the dynamics of the mangove system are presented in subsequent chapters.

Aquatic primary productivity and mangrove forest productivity have been studied and detail presented. Mangrove litterfall production has been estimated as 739.5 $g/m^2$/annum and the quantity exported to the adjacent aquatic system as 4t/ha/annum.

Mangrove community structure and relevant parameters such as basal area, density, height and frequency have been analysed and presented with indices such as Importance Value, Complexity Index, and Shannon Index.

The role of the mangrove ecosystem as a nursery ground for commercially important species of prawns and feeding ground for finfishes especially during their early life history stages has been highlighted in the next chapter with information on the indiscriminate exploitation of juvenile population of species such as Metapenaeus dobsoni within the estuary by fixed nets such as stake nets. The effect of such destructive type of fishing on coastal stocks have been discussed.

Various threats to the mangrove ecosystem in the study area have been outlined. In the light of the studies made by the candidate, conservation measures to be undertaken for the rehabilitation of the mangrove habitat protection and revival of vulnerable species have been recommended. Some management strategies relevant to the study area as a whole have also been suggested.

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# REFERENCES


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