CONSERVATION AND MANAGEMENT OF MANGROVES

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IN
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BY

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CERTIFICATE

This is to certify that the thesis entitled "**Conservation and Management of Mangroves**" submitted by Shri Rajiv Kumar for the award of the degree of **Doctor of Philosophy** in Botany, is based on the results of investigations carried out by him under my guidance and supervision. The thesis or part thereof has not been submitted previously for any degree.

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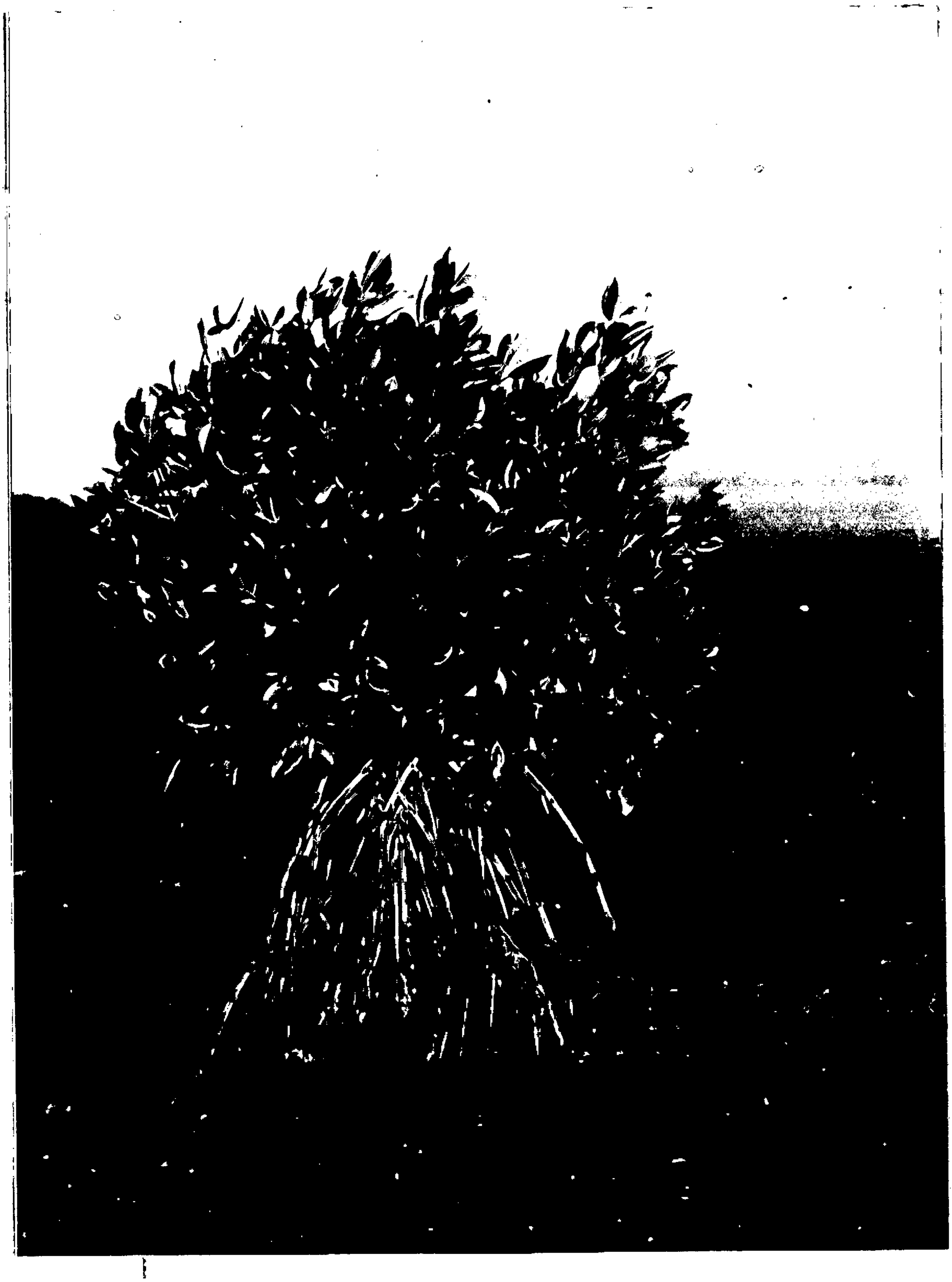

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An isolated young plant of *Rhizophora mucronata* at Chorao (Goa)

CHAPTER-1

GENERAL INTRODUCTION

1.1. HISTORICAL ACCOUNT OF MANGROVE ECOSYSTEM

Mangrove ecosystem is one of the most productive natural ecosystems on the earth with great ecological and economic significance. It is widely believed that mangrove forests developed first in the Indo-Malaysian region and then spreaded to other regions of the tropics. This region is, therefore, considered as the cradle of evolution for mangrove vegetation (Krishnamurthy, 1993).

Among various species of mangroves, *Rhizophora* species is the most familiar mangrove primarily due to its conspicuous stilt roots, which start developing at a young stage of 2-3 years (personal observation). Plate-1.1 shows an isolated young plant of *Rhizophora mucronata* with stilt roots at Chorao (Goa). Portuguese were probably the first foreigners to visit mangrove forests of the Indian Ocean around 14th century and called them "*mangue*". The Portuguese learned from the Indian people how to use the mangroves to create rice-fish mangrove farms and this traditional knowledge was described in the letters of the Viceroys written to the King of Portugal (Vannucci, 1997). This Indian technology was transferred by Jesuit and Franciscan fathers to the African countries such as Angola and Mozambique where the local people were trained in the Indian techniques, around six centuries ago (Vannucci, 1997). The mangrove management practices started first in Indian mangroves. In the 19th century, the

British applied practical knowledge gained over centuries for the management of the Sunderbans mangrove forest for timber extraction (Vannucci, 1997). Similar timber extraction practices were adopted in Malaysia and Indonesia.

The mangroves are also considered as the sacred forests in some parts of the world. For example, in the Solomon Islands, the dead bodies are disposed and special rites are conducted in the mangrove waters (Vannucci, 1997). In Kenya, the local community worships "shrines" that are built inside the mangrove forests. The community believes that if the trees around the shrines are cut, the spirits of the shrine will kill the woodcutters. A mangrove tree namely, *Excoecaria agallocha* is worshipped as a temple tree at the Lord Nataraja temple at Chidambaram (Tamilnadu). In this temple, mangrove tree is carved on the rock as sculpture, which is worshipped by the people belonging to the "*Hindu*" religion. This sculpture was made in the temple, around 2nd-3rd century.

One of the earliest known references to the mangroves is that of Europeans who described the mangroves of the Arabian Gulf about 2,000 years ago. Even prior to this, the coastal mangroves were cited in the ancient Tamil literature. These facts reveal that the Indians understood the value of mangrove forests, well before any one else in the world to think of the mangrove forests.

Indians have a high aesthetic sense. For instance, the mangrove species, "*Heritiera fomes*" was named as, "*Sundri*" and mangrove forests of Bengal were named as Sunderbans, which means beautiful forests (*Sunder/ Sundri* means beauty and *Bans* means forests in Bengali, Hindi and Sanskrit languages). Besides this, Indians used to name the places in scientific style. For example, a place, north of Chennai, is named after the mangrove forest as *Pazhaver-kaadu* (in Tamil, *Pazhaver* means rooting from fruits that is viviparous germination and *Kaadu* means forests).

The Indian mangroves received early attention in 17th century itself. Van Rheede in 1678 was first to provide a scientific account on Indian Ocean mangroves, in "*Hortus Malabaricus*" (Chapman, 1976; Untawale, 1987). The Royal Botanical Gardens took keen interest in the flora of the Sunderbans and other mangrove regions. Roxburg (1814) described the flora of the Sunderbans, in his work "*Hortus Bengalensis*". Another comprehensive account of the Sunderbans was presented to the Linnaean Society of London by Clarke in 1896. Schimper (1891) published a book "*Die Indo- Malayische Strand –flora*". In the meanwhile, Sir Hooker released "*Flora of India*". Later, Prain (1903) published a compilation entitled "*Records of Chronicle of the Survey of India*". Subsequently in the 20th century, many works came to limelight viz. Hooker, (1872); Blatter, (1905); Cooke, (1908); Curtis, (1933); Champion, (1936); Troup, (1921); Griffith, (1936); Cornwell, (1937); Navalkar, (1951); and Krishnamurthy *et al.*, (1987).

1.2. MANGROVES AND THEIR SIGNIFICANCE

Mangroves are the characteristic littoral plant formations of tropical and subtropical sheltered coastlines. They have been variously described as *'woodland'*, *'tidal forest'* and *'mangrove forest'*.

Generally, mangroves are trees and bushes growing below the high-water level of spring tides (FAO, 1952). Their root systems are thus regularly inundated with saline water, even though it may be diluted due to freshwater surface run-offs.

Davies (1940) described "Mangrove" as a general term applied to plants, which live in muddy, loose, wet soil of tropical tidal waters.

Macnae (1968) defined mangrove as trees or bushes growing between the level of high water of spring tide and a level close to but above mean sea level. Macnae adopted the term "*Mangal*" to deal with the mangrove plant community and the term "Mangrove" is used to describe either mangrove ecosystems or the component vegetation or both.

Auberville (1970) defined mangrove as coastal tropical formations found along the border of the sea and lagoons reaching up to the edge of the rivers to the point where water is saline, growing in swampy soils and covered by the sea during high tides.

According to Clough (1982) mangroves are the only trees amongst a relatively small group of higher plants that have been remarkably successful in colonizing the intertidal zone at the interface between land and the sea.

The mangrove ecosystem consists of the intertidal flora and fauna found in the tropics as well as subtropics and dominated by evergreen broad leaved trees with stilt roots or pneumatophores and viviparous seedlings (UNESCO, 1973).

The mangroves were considered wastelands in most part of the world and were either ignored or abused, until the late 1960s (Snedaker, 1987).

1.2.1. ENVIRONMENTAL AND ECOLOGICAL SIGNIFICANCE OF MANGROVE ECOSYSTEM

The mangrove ecosystem has been identified as very unique but fragile, dynamic and most productive than any other ecosystem. (Naskar & Ghosh, 1989).

Mangroves maintain atmospheric equilibrium in coastal areas

During the process of photosynthesis, mangrove trees release oxygen and maintain gaseous balance in the atmosphere. Transpiration from leaves control temperature and humidity in the coastal area. Atmospheric equilibrium is most vital for survival of all forms of life. By the presence of secondary metabolites such as anthocyanin and flavonoids, the mangrove leaves appeared to absorb solar UV-radiation and make the environment less hazardous (Moorthy, 1995).

Mangroves check the soil erosion and help in stabilization of coastlines

Macnae (1968) reported that the undisturbed and natural mangrove forests or ecosystem might act as the seaward barrier and check considerably the coastal erosion and minimise the tidal thrust or strong storm hit arising from the sea. Carter (1959) reported that frequent erosion occurred on the mangrove cleared or degraded coastal zones.

Mat like spreading of root system in the form of pneumatophores, stilt roots and soil binding ability of mangrove species check soil erosion and ensure stabilization of the coastlines. Mangroves help in maintaining suitable condition in the agricultural fields close to the coastal areas by preventing sand particles and saline water from entering into the agricultural fields (Snedaker, 1987; Dagar, 1982, 1987). The maintenance of mangroves in Indus delta of Pakistan has protected part of the coast from wind erosion (Qureshi, 1996).

Mangroves as life supporting system

Fallen leaves and other plant materials decomposed by the micro-organisms act as food for various types of marine organisms including fishes and prawns. Mangrove roots in the form of stilt roots and pneumatophores provide excellent breeding and resting ground for various types of fishes, crustaceans and other marine fauna. Thus, mangroves support life in marine environment (Dagar, 1982, 1987). Mangrove detritus and the subsequent mineralised nutrients are exported out of the mangrove ecosystem through tidal flashing. These are found in the food base for marine micro-organisms and these in turn support the valuable estuarine and near shore fishery (Naskar & Mandal, 1999).

Role of mangroves in building new islands

Mangroves are really the builders and guardian of the land (Sahni, 1957). They grow seaward, sending their spreading roots into the shallow water. Typical root system of mangrove traps the sediments, which are brought along with run-off from the river catchment areas. Amount of erosion and sediments deposition depends largely on the vegetation present in the catchment areas. Well-developed mangrove habitats may also accelerate the siltation and accretion processes by arresting the water transported silt and clay particles, which ultimately built or extend the coastal zone through accretion (Chatterjee, 1957; Naskar & Mandal, 1999).

Mangroves as Wind breaker

Mangroves in the coastal area check the wind velocity and protect the nearby habitation from cyclonic winds (Snedaker, 1987). Mangrove coverage may act as a buffer agent and protect or minimise the natural cyclone or surges of the bay considerably (Naskar & Guha Bakshi, 1987).

Habitat for Wild life

During the course of study various types of reptiles such as crocodiles, snakes, monitor lizard and different types of birds were noticed in mangrove forests. Crocodiles are common in Cumbarjua canal of Goa and also in Andaman, while different types of birds can be seen in the mangrove forests at Chorao Island (Goa). Mangrove forests are an important habitat for mammals, birds, reptiles, fish, molluscs, insects and micro-organisms (Field, 1996).

Scenic beauty

Presence of mangroves along the sea coast and estuaries add scenic beauty to the area. Mangroves can be seen in Goa in the heart of Panjim City near Patto Bridge, which adorn the city.

High Biodiversity and Nature's Gene Bank

Mangrove ecosystem is a storehouse of variety of fauna and flora with great ecological and economical significance. Macnae (1968) gave a general account of the fauna of mangroves in the Indo West Pacific Region. Saengar *et al.,* (1983) described the global status of mangrove ecosystem including their fauna. Das and Siddiqi (1985) compiled the information on wild life species (mammals, reptiles, amphibians and birds) found in Sunderbans. Das and Dev Roy (1989) gave a general account of the mangrove fauna of Andaman and Nicobar Islands. Central Agriculture Research Institute (CARI), at Port Blair, Andaman and Nicobar Islands has recently reported presence of nearly 200 species of insects associated with mangroves that feed on mangrove tissues.

Only a few mammals live in mangrove areas and fewer are restricted to them (FAO, 1982). Royal Bengal Tiger and the spotted deer are common in mangrove areas of Sunderbans. Wild boars are sometimes seen in *Nypa* swamps. Some small carnivorous animals such as civets, fishing cats, otters and mongooses are common in mangrove forests. The Malaysian probosis monkey is endemic to mangroves of Borneo where it feeds on foliage of *Sonneratia caseolaris* and *Nypa fruticans* (FAO, 1982).

Crocodiles and alligators are some of the most important reptiles that naturally inhabit the mangrove ecosystem. The salt water crocodile, (*Crocodilus porosus*) is found in almost all large islands of Andaman and Nicobar which support extensive mangrove swamps and tidal creeks (Tikader and Das, 1985).

Mangrove forests are ideal sanctuaries for avifauna. According to Saenger *et al.*, (1983), the total list of mangrove bird species in each of the main bio-geographical regions includes from 150 to 250 species. All over the world, 65 bird species have been listed as endangered or vulnerable. Das and Dev Roy (1989) have reported 53 species of birds observed by them in the mangrove areas of Andaman and Nicobar Islands. Out of these 53 species, 30 are endemic, 12 resident, 10 winter visitors and one is an introduced species. Some of the birds found in mangrove forests of Andaman and Nicobar are Andaman Little Green Heron, Andaman Grey Teal, Andaman Green Imperial Pigeon, Large Andaman Parakeet, Andaman Crow- Pheasant, Andaman Greyrumped Swiftlet, Andaman Black Woodpecker, Andaman Rocket tailed Drongo, Common Myna, Mangrove Whistler and Andaman Olivebacked Sunbird.

Seidensticker and Hai, (1983) have reported over 120 species of fish caught by fishermen in the Sunderbans. Das and Dev Roy (1989) reported several economically important molluscs and crustaceans from mangrove ecosystems of Andaman and Nicobar Islands, which are given in Table- 1.1.

The mangrove ecosystem is the important 'gene pool' of several endemic flora and fauna, which are also included in the Schedule-I of the Wild Life Protection Act, 1972 and several other subsequent Protection Acts (Naskar & Mandal, 1999). Mangrove ecosystem is equally rich in mangrove flora. Conservation of mangrove ecosystem ensures biodiversity conservation and the ecosystem itself plays its role as Nature's Gene Bank.

TABLE-1.1

ECONOMICALLY IMPORTANT FAUNA OF MANGROVE ECOSYSTEM OF ANDAMAN AND NICOBAR ISLANDS

MOLLUSCA	**CRUSTACEA**
Gastropods	**Crabs**
Strombus (Canarium) erythrinus	*Scylla serrata*
Strombus (Dolomena) variabilis	*Thalamita crenata*
Lambis (Lambis) lambis	*Thalamita prynma*
Bivalves	**Shrimps**
Geloina galatheae	*Penaeus semisulcatus*
Geloina siamica	*Penaeus indicus*
Batissa inflata	*Penaeus monodon*
Batissa similis	*Acetes sp.*
Codakia tigerina	**FISH**
Paphia malabarica	*Anguilla bicolor*
Gafrarium tumidum	*Anguilla bengalensis*
Meretrix attenuata	*Sardinella spp.*
Donax cuneatus	*Liza macrolepis*
Donax lubricus	*Velamugil cunnesius*
Perna viridis	*Ambassis commersoni*
Placuna placenta	*Ambassis gymnocephalus*

SOURCE: Das and Dev Roy (1989)

1.2.2. ECONOMIC SIGNIFICANCE OF MANGROVE ECOSYSTEM

Mangroves for fuel wood

Mangrove wood is well known for its high calorific value, therefore, preferred as fuel wood since time immemorial. The trees and shrubs, which can be used for this purpose, include *Rhizophora, Avicennia, Excoecaria, Ceriops, Bruguiera* and *Sonneratia*. The coastal people of tropical and sub tropical countries extensively use mangrove wood as firewood. *Rhizophora* species are especially popular, as the wood is tough, dense textured, strong, very hard, heavy and burns with an even heat with little smoke. It ignites easily even when partially wet. *Avicennia* wood has low calorific value but its clean white smoke is suitable for smoking fish. *Excoecaria, Aegiceras, Sonneratia* species are locally used as firewood in virtually all countries in the tropics and sub tropics. The average yield of firewood is 10 tonnes/ acre (Banerjee, 1957). Exploitation of mangroves is commonly practiced in Matang (Malaysia) and Tuck (1987) has reported that the firewood is sold at the rate of 25 US $ per ton. The most important uses of mangrove in some countries listed by FAO (1982) are summarized in Table-1.2. Properties and qualities of mangrove wood that make them the best kind of fuelwood are given in Table-1.3.

TABLE –1.2

MAJOR USES OF MANGROVES IN SOME COUNTRIES

Country (area)	**Major Economic Species/Family**	**Major Uses**
India arid Zone	*Avicennia*	Firewood, fodder
Sunderbans (Indian and Bangladesh)	*Heritiera, Excoecaria*	Timber, firewood
Thailand	*Rhizophora*	Charcoal
Vietnam	*Rhizophora*	Charcoal, firewood, poles
Malaysia-West	*Rhizophora*	Charcoal, poles
Malaysia-East	*Rhizophoraceae*	Chips (pulp)
Indonesia-Sumatra	*Rhizophoraceae*	Charcoal, poles, chips
Indonesia-Java	*Rhizophoraceae*	Firewood
Indonesia-Kalimantan	*Rhizophoraceae*	Chips
Phillipines	*Rhizophoraceae*	Firewood
Papua New Guinea	*Rhizophoraceae*	Firewood, poles, posts
Pacific	*Rhizophoraceae*	Firewood, poles, posts

SOURCE: FAO, 1982

TABLE-1.3

PROPERTIES OF MANGROVE WOOD

Name of Species	Calorific value (cal)	Weight (kg/cu. ft.)	Hardness	Specific Gravity	% of ash
Rhizophora mucronata	4,888	23	Very hard	0.81	0.9
Bruguiera gymnorrhiza	4,700	28	Hard	-	1.1
Ceriops tagal	5,150	25-30	Hard	-	1.1
C. roxburghiana	5,347	21-25	Hard	-	-
Heritiera minor	5,028 (sapwood) 5,261 (Heartwood)	26-30	Very hard	0.84	1.9
Sonneratia apetala	4,901 (sap wood)	18	Moderate	0.60	2.2
Lumnitzera racemosa	5,137 (sap wood) 5,424 (Heart wood)	24-26	Hard	-	0.6
Excoecaria agallocha	4,767	-	Soft	-	3.18
Aegiceras corniculatum	Very low	18	Moderate	-	0.9

SOURCE: Untawale (1998)

Charcoal

Wood from mangrove forests is used widely throughout the tropics and sub-tropics for charcoal production. *Rhizophora* species make charcoal of excellent quality (FAO, 1994). Other mangrove species like *Bruguiera*, *Ceriops* and *Heritiera* are also used for charcoal making but are quantitatively less important (Aksornkoae, 1985). Species of the family *Rhizophoraceae*, mainly *Rhizophora apiculata, R. mucronata* and *Bruguiera parviflora* and *B. gymnorrhiza* are particularly favoured for making charcoal because of their hard timber with high calorific values (Jara, 1985). Mangrove wood is largely used for making charcoal in Thailand, Vietnam, Malaysia, Indonesia and Sumatra (Table-1.2).

Source of wood to be used as timber and for other purposes

Mangroves grow within the saline environment in the inter-tidal region; therefore, it's wood is normally resistant to termite and other insects. It can withstand water logging and direct sunshine. Wood obtained from *Excoecaria agallocha* is light in weight and is used for carpentry works, building construction, making fishing boats, packing boxes and match splints. Timber obtained from *Rhizophora* and *Bruguiera* species can be used for building construction. Wood obtained from *Avicennia* species can be used for building construction, furniture, plywood, agricultural implements etc. Wood obtained from *Ceriops* can be used for cottage making and also for fencing works (FAO, 1994).

Source of fodder

Cattle, goats and buffaloes are the domestic animals known to graze on mangrove foliage. Leaves of some mangrove species like *Avicennia marina* and *Bruguiera* *parviflora* are used as fodder for milching animals. Cattle and goats can be seen grazing on these mangrove species in Middle Andaman Island. In terms of nutritive value, mangrove leaves are ranked among the best. Hamilton and Snedaker (1984) found that *Avicennia marina* was most nutritive.

Camels, goats and cattle in India, Pakistan and the Arabian coast graze *Avicennia* leaves. In Australia, wild buffaloes graze on mangroves in the Northern Territory. This sight can also be seen in Vietnam. The stall feeding of sheep and pigs has been practiced in a number of countries using mangrove fodder in conjunction with other feedstock (FAO, 1994).

Source of tannin

Barks of mangrove trees and shrubs are rich source of vegetable tannins. They contain commercially important tannin material. Tannins have been studied for their seasonal changes in 14 mangrove species and the tannins ranged from 2.41 to 21.42 mg/g dry weight (Katheresan and Veera Ravi, 1990). *Rhizophora* bark produces very fine tannin suitable for leather work. Tannin from mangrove species has also been used for curing and dyeing of fishing nets made of natural fibre to make the nets more resistant to biological decay (FAO, 1994).

Source of wax and honey

Mangrove forests have substantial potential for production of wax and honey. Honeybees build honeycomb on the higher branches of the mangrove tree and collect nectar from mangrove flowers. Honey collection from mangrove forests is flourishing in India. It has been estimated that the Sunderban mangrove forest alone produces about 111 tonnes of honey annually (CIFRI 1973). There are approximately 2,000 people engaged in this trade. This activity of honey and wax production can develop employment opportunity and also become source of revenue. Honey collected from *Cynometra ramiflora* and *Aegialitis rotundifolia* has a good market value and is in demand. However, honey from other species like *Ceriops* and *Excoecaria agallocha*, although common, is not highly valued (Blasco, 1975).

Source of medicine

Mangrove plants possess medicinal properties and are used by tribals in Andaman and Nicobar as medicine for treatment of several diseases (Dagar and Dagar, 1986; Dagar, 1989). Medicinal properties of mangroves have also been reported elsewhere (Chapman, 1976; Chopra *et al.*, 1956; Anonymous, 1948 to 1976). Some of the reported medicinal uses on mangroves are as follows:

Acanthus ilicifolius - Leaves reported to be used for treating rheumatism and neuralgia.

Acrostichum aureum - In Malaya and Borneo, the pounded rhizome is applied to wounds and boils.

Ceriops tagal - Decoction of shoots used as substitute for quinine.

Heritiera littoralis - Decoction of seeds is used in diarrhea and dysentery.

Xylocarpus granatum and *X. moluecensis* - Bark is used as febrifuge and in dysentery by the Nicobarese.

Raw material for paper making

Excoecaria agallocha is the principal pulping species used in the newsprint mill in Bangladesh. *Sonneratia caseolaris, Excoecaria agallocha* and *Avicennia marina* produce strong Sulphate pulps. The African species of *Rhizophora racemosa* is reported as suitable for making dissolved pulp although some problem exist due to the inorganic crystals present in the wood (Sugden and von Cube, 1978). Some mangrove species like *Rhizophora mucronata* possess satisfactory properties for making writing and printing paper.

Mangroves for boosting fish and prawn production

Importance of the mangrove ecosystems in fisheries has been established (Purushan, 1991; Agate, 1991; Jeyaseelan *et al.*, 1991). With a high rate of primary production, they are able to sustain populations of fish, shellfish and wildlife. Shellfish includes molluscs (Gastropods and Bivalves) and crustaceans (crabs and shrimps). Mangroves serve as the primary breeding and nursery grounds for many animal species especially for prawns.

No mangroves, so no prawns said Macnae, (1968). Mangroves serve as custodians of their juvenile stock and as natural wealth (Kathiresan, 1995a). Small scale fisheries in mangrove waters produce nearly one million tons of finfishes, molluscs, crabs and shrimps annually, that is equivalent to about 1.1 per cent of the world fishery catch (Kapetsky, 1985). Mangroves provide direct employment for about 0.5 million fisherfolk. A total of about one million jobs worldwide is dependent on mangrove-associated fisheries. The density of population dependent on mangroves is estimated about 5.6 persons/ sq km (FAO, 1988). Besides the capture fishery, culture fishery is also prevalent in the mangrove-rich areas. Mangrove forests are excellent breeding and resting ground for various fishes, prawn and other crustaceans. Thus, mangroves help in multiplication of fishes and prawns.

Eco-tourism in mangrove forest

As mangrove forests are inhabited by variety of animals and birds, they can be converted into wildlife sanctuaries. Eco-tourism can be introduced in such areas for educational and recreational purposes. Ecó-tourism potential can be realised if the mangrove resource is well protected to motivate rural population, maximise economic benefits and minimise environmental costs (FAO, 1994).

Fish poison

Bark of *Derris heterophylla* and milky latex of *Excoecaria agallocha* are used as fish poison (Dagar, 1982; 1987).

Miscellaneous

Investigations have shown that some of the mangrove vegetation can serve for a variety of purposes: -

(i) Mangroves are rich in polyphenolic compounds, therefore, leaves were attempted for making a beverage similar to tea. The mangrove tea as beverage has been proved to have better quality and no mammalian toxicity (Kathiresan, 1995c). Further attempt has been made to improve the quality of tea by UV-radiation treatments (Kathiresan and Pandian, 1991, 1993).

(ii) As a cholesterol-feed for prawn

(iii) As potential sources of mosquitocides. Mangrove plants have been reported for the first time to control the activity of mosquitoes (Subramonia Thangam, 1990). Plant extracts kill mosquito larvae of *Aedes aegypti, Culex tritaeniorhynchus* and *Anopheles stephensi.* The plant extracts were found to show repellent activity against *Aedes aegypti* when the extracts were applied on the human skin. Smoke repellency and killing effect of mangrove plant extracts were found against *Culex quinquefasciatus* and *Aedes aegypti.* (Thangam and Kathiresan, 1992 a, 1993 and 1994).

(iv) For anti-viral drugs formulation- especially against AIDS and jaundice

(v) As a source of UV-absorbing compounds

(vi) As a source of bacterial biofertilizers

(Subramonia Thangam, 1990; Premanathan, 1991; Moorthy, 1995; Ravikumar, 1995; Palaniselvam, 1995; Moorthy and Kathiresan, 1995; Kathiresan, 1995a). Studies on these aspects will prove the efficacy of the mangrove plants in the aspects of therapeutic, preventive and clinical medicines as well as in agriculture.

FAO, (1994) has listed various mangrove-based products and other natural products from the mangrove ecosystem (Table-1.4).

TABLE-1.4

MANGROVE-BASED PRODUCTS

A. Mangrove Forest Products	Sweetmeats (propagules)
Fuel	Vegetables (fruit/leaves)
Firewood	
Charcoal	Household items
Construction	Glue
	Hair dressing oil
Timber, scaffolds	Tool handles
Heavy construction	Rice mortar
Railway sleepers	Toys
Mining props	Match sticks
Boat building	Incense
Dock pilings	
Beams and poles	Agriculture
Flooring, panelling	
Thatch or matting	Fodder
Fence posts, chipboards	
	Paper products
Fishing	
	Paper – various
Fishing stakes	
Fishing boats	Other products
Wood for smoking fish	
Tannin for net/lines	Packing boxes
Fish attracting shelters	Wood for smoking
	sheet rubber
Textile, leather	Fuel wood for :-
	salt making
Synthetic, fibres (rayon)	brick kilns
Dye for cloth	bakeries
Tannin for leather preservation	tobacco drying
	medicines
Food, drugs & beverages	
	B. Other Natural Products
Sugar	
Alcohol	Fish/Crustaceans
Cooking oil	Honey
Vinegar	Wax
Tea substitute	Birds
Fermented drinks	Mammals
Desert topping	Reptiles/Other fauna
Condiments (bark)	

SOURCE : FAO, 1994

1.3. ENVIRONMENTAL FACTORS RESPONSIBLE FOR THE GROWTH AND DISTRIBUTION OF MANGROVES

Climatic, Edaphic and Biotic factors largely govern the growth and distribution of mangroves.

1.3.1. CLIMATIC FACTORS

Pannier and Pannier (1977) broadly summarized the present knowledge concerning the distribution of mangrove forests in relation to climatic regions. According the Walter (1977), mangrove ecosystems are mainly found in three climatic divisions, viz.,

(a) The equatorial zone, between approximately 10°N and 5°-10°S;

(b) The tropical summer rainfall zone, north and south of the equatorial zone, to approximately 25-30°N and S, partly in subtropical dry zone of the deserts, still further poleward, and

(c) Partly in warm temperate climate that do not have really cold winters, and only on the eastern border of the continents in this zone.

Blasco (1984) suggests that both temperature and rainfall should be shown in a single climatic diagram, because they are essential bioclimatic factors for mangroves and other terrestrial plants.

a) Temperature

Temperature is an important factor in the growth and distribution of mangroves (Chapman, 1977). These plants require warm, tropical climate to develop. The average temperature of the coldest month should be above 20°C (Dawes, 1981). Accordingly, mangals are most extensively developed on tropical shores. Even in a continuously humid climate the number of mangrove species decreases with distance from the equator. The maximum number of species are found on the coasts of Malaysia, Indonesia and New Guinea (Rao, 1987). With lower temperatures, there is only one species in "South Japan", south of the equator and only *Avicennia marina* var. *resinifera* remains as the most frost resistant species in southern Australia and northern New Zealand (Chapman, 1977). Studies in Japan show that the area occupied by mangrove forests and the diversity of the species occupation decrease with increasing latitude and at the northern limit, the mangrove is represented by stands of only one species, *Kandelia candel* (Hosokawa *et al.*, 1977). Mangroves prosper in the regions with continuous high temperature and prolific rainfall. Mangroves are very sensitive to frost and cold climate, therefore, restricted to tropical and subtropical regions of the world (Walter, 1977).

(b) Winds and Storms

Mangroves require sheltered places to grow. The impact of severe storms on the forest can be profound. In areas that are exposed to severe storms the canopy of the forests along the coasts is usually broken. Structurally, the trees are also shorter. This partly explains the fact that high mangroves are found generally in more sheltered situations (Dagar *et al.*, 19 91).

(c) Rainfall

The amount of fresh water supply, which comes from rainfall, also affects the growth and distribution of mangroves. Rainfall influences the distribution of species because it directly recharges the ground water system and affects subsurface seepage along the hinterland edge (Semeniuk, 1983). Mangroves do not rely absolutely on rainfall for survival because they can extract fresh water from the sea through salt excreting glands, (Chapman, 1976). However, the amount of rainfall influences mangroves in two ways:

(A) Rainfall determines the rate of weathering, it accounts for the amount of silt brought to the mangrove swamp, and

(B) High rainfall reduces the incidence of hyper-salinity.

Fresh water flow from upland brings nutrients and silt, important for the growth of mangroves. Thus, well-developed mangal formations are on muddy coastal plains where adequate fresh water supplies from river discharge are available. According to Macnae (1966, 1968), Australian mangroves thrive best in areas receiving more than 2,500 mm of rain per year.

(d) Tides and Tidal Currents

Tide is a periodic raising and falling of sea level caused by the gravitational attraction between the Moon, the Sun and the astronomical bodies acting on the rotating Earth. The vertical rise and fall is called *tide* or *astronomical tide*, the horizontal movement of water is termed *tidal current.* Tides follow the Moon more closely than the Sun.

Periodic seawater inundation over mangrove land is necessary for the development of mangroves. This is dependent on the tidal pattern (that is whether one or two tides per day, the spring tide versus neap tide ranges) and on the height of shore above mean sea level. These factors will determine not only how often, but also to what depth mangrove species are inundated (Macnae, 1968). The best mangal formation occurs when the shores are sheltered from strong wave action, as strong tides and wave action erode established mangals and hinder the establishment of seedlings (Semeniuk *et al.*, 1978). Therefore, it follows that mangals are best developed along coasts such as inlets, lagoons and gulfs where the environment is protected from strong currents and waves. Further, a coastline with a gently sloping shore profile offers a good substrate for the growth of well-developed mangroves forests with distinct tree zonation (Rao, 1987). A combination of lowland slopes with great fluctuation of water results in an extensive mangrove (Odum and Heald, 1975). The shallow, extensive slope inland ensures the settlement of sediments which is necessary for seed development (Dawes, 1981). Water movement is very important for the survival of mangroves. Nutrients are brought into the system by the tides and from upstream flows. Tides carry the remains of these nutrient detritus from the mangrove ecosystem further downstream to the estuarine systems (Dwivedi, *et al.*, 1974; Lugo, *et al.*, 1973). Water transports dissolved oxygen to the root system of the plants and recycles nutrients in the ecosystem (Clough, and Attiwill, 1974). Tides remove accumulated carbon dioxide, sulphurous toxic wastes, organic debris, and maintain soil salinity levels. The dispersal, dispersion and successful establishment of propagules are also partly influenced by tides (Chapman, 1976; Rabinowitz, 1978)

Tides also regulate benthonic activity. Filter feeders, such as clams, mussels, oysters (Molluscs) depend on the tides. Gocke *et al.*, (1981) have shown that tidal range and duration of immersion affect the relative percent of oxygen consumption of benthic organisms in different habitats along the Pacific coast.

1.3.2. EDAPHIC FACTORS

These constitute the composition, structure and other interrelated properties such as salinity, nutrient content, permeability and drainage. A saline environment is required for stable mangrove ecosystem (Lugo, 1980). However, the hypersalinity can adversely affect mangroves. A particular site is considered to be hypersaline if the salinity exceeds the salinity prevailing in the sea. In most of the areas, this is 35 ppt on an average. Zonation in mangroves is partly governed by the salinity although the extent of its influence depends on local climatic and edaphic factors (Fradin, 1985). The daily variation and annual average of salinity affect the mangrove growth and distribution (Soegiarto, 1984).

The alluvial soil is rich with ferrous sulphides, which are the ferric compounds reduced by hydrogen sulphides. The soil is mostly anoxic except for the surface layers in which the roots are spread (Rao, 1987). For this reason, mangroves have a shallow root system.

Mangrove soils are mostly alluvial in nature. They have a high salt and water contents. They also have low oxygen and abundant hydrogen sulphides. They are fine-grained soils, often semi-fluid, consolidated poorly and with abundant humus in parts (Macnae, 1968). The type of soil affects the type of plants growing in it, for example, *Rhizophora mucronata* and *R. stylosa* dominate in muddy and sandy substrates, respectively. Troll and Dragendorff (1931) considered that the black colour of mangrove mud is produced by anaerobic bacteria reducing sulphates into sulphides.

Edaphic and physical factors interact together. Soil salinity depends on evaporation, waterlogged nature of the soil, frequency of tidal inundation and the possibility of fresh water influx. Occurrence of many mangrove species appear to be markedly controlled by soil salinity, for example, *Ceriops* can tolerate up to 60 parts per thousand (ppt) salinity and will grow in very saline soils.

Drainage also influences the properties of soil as it is related to soil properties, slope of surface and the presence of local creeks. It is an important factor in the survival of mangroves since some species require well-drained soils whereas others can flourish in poorly drained waterlogged soils.

Geomorphologically, large mangrove formations are typically found on relatively sheltered deltaic littoral plains.

1.3.3. BIOTIC FACTORS

Interspecies competition and interaction can be an important factor in mangroves species diversity, for instance the *Rhizophora* canopy, by excluding light, can inhibit the establishment of other mangrove species. Establishment of the fern *Acrostichum aureum* will not allow the seedlings of other mangrove species. Pneumatophores of *Sonneratia* and knee roots of *Bruguiera* protect young trees from wave damage. Organisms such as bacteria and fungi contribute to the fertility of the mangrove area by decomposing fallen leaves and other plant parts. During microbial growth, the soil becomes enriched with compounds released by the decomposition process. The mud lobster and burrowing crabs contribute significantly to the mangrove ecosystem. Clays are mined, mixed thoroughly and thrown into mounds. These mounds play a role in succession as plants such *as Lumnitzera, Acrostichum,* and *Heritiera*, establish on them. Some activities of the animals are directly harmful such as the damage to the seedlings and fruits etc. The role of man in changing the mangrove ecosystem is of great significance.

Some of the environmental factors mentioned above are interrelated. For instance, with a sloping coastline, frequency of tidal flooding decreases upslope and if the climate is dry, salinity increases. Similarly, poorly drained soils tend to remain waterlogged and if subjected to intense evaporation can become excessively saline. Where the environmental factors are well differentiated along a shore of gentle gradient, there will be a tendency for the development of distinct broad zones of mangroves.

1.4. GEOGRAPHICAL DISTRIBUTION, AREA AND SPECIES DIVERSITY IN MANGROVES

1.4.1. GLOBAL SCENARIO

As far as geographical distribution of mangroves around the globe is concerned, they are growing on sheltered coastlines, mud fields and riverbanks in many part of the world. Mangrove regions of the world have been divided into two broad categories namely Atlantic East Pacific and Indo West Pacific. Atlantic East Pacific region has been further divided into three sub regions namely West America, East America and West Africa. Similarly Indo West Pacific region has been divided into three sub regions namely East Africa, Indo Malaysia and Australia (Figure-1.1; Duke, 1992).

The total mangrove area in different parts of the world is not precisely known. However, Table-1.5 gives approximate mangrove areas in various countries. The world's greatest contiguous mangrove area in the Sunderbans (India and Bangladesh) situated in the Bay of Bengal, which covers total area of approximately 6,60,000 ha. World's total mangrove area is approximately 1,65,30,000 ha or 1,65,300 sq kms.

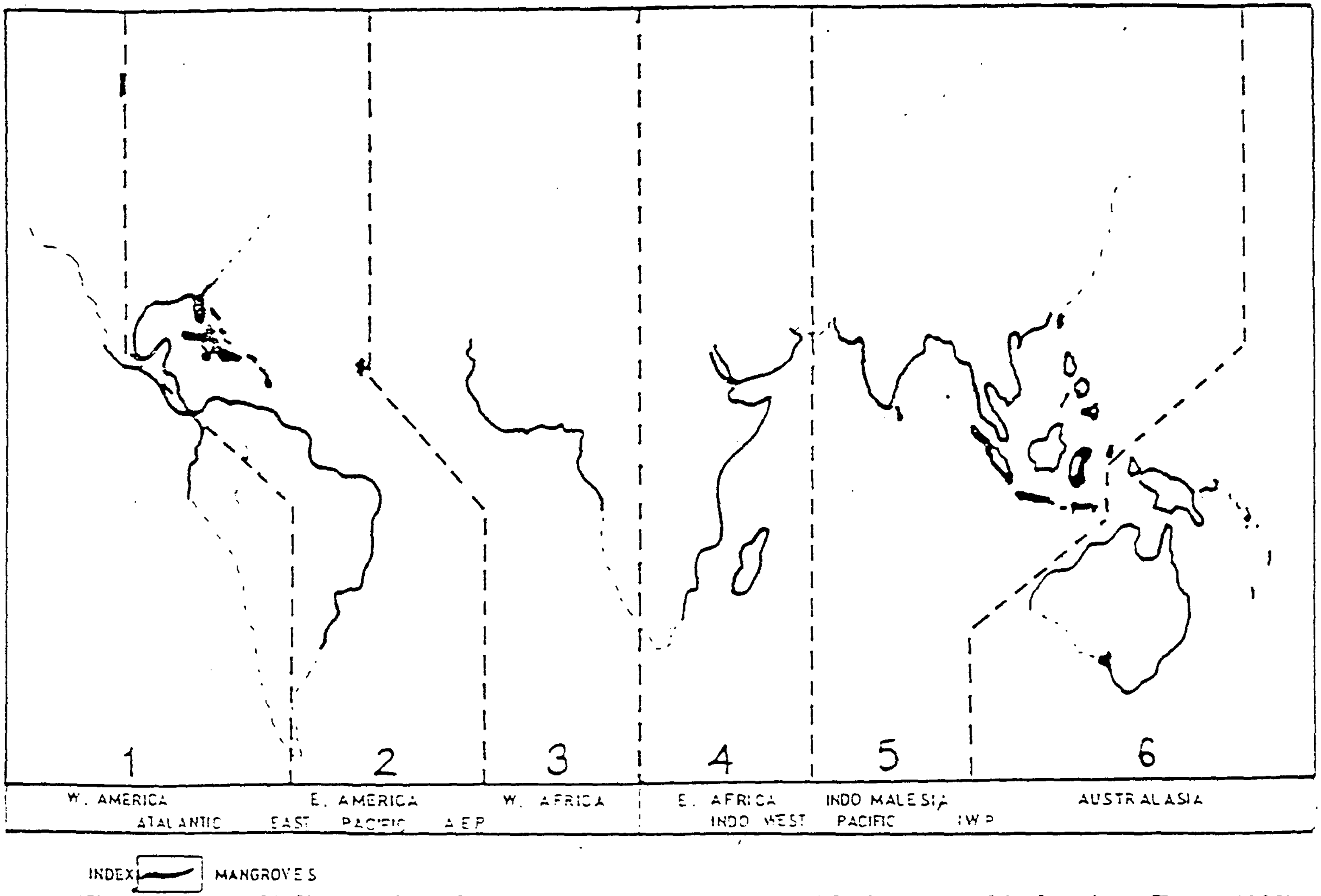


Figure-1.1 World distribution of mangroves showing extent with six geographical regions (Duke, 1992)

TABLE-1.5

APPROXIMATE MANGROVE AREAS IN VARIOUS COUNTRIES

ASIA	Area (ha)*	AFRICA	Area (ha)**	AMERICA	Area (ha)***
Australia	1,162,000	Angola	50,000	Belize	75,000
Bangladesh	410,000	Benin	3,000	Brazil	2,500,000
Burma	812,000	Cameroon	273,000	Colombia	307,000
Brunei	7,000	Gabon	250,000	Coata Rice	19,000
Fiji	20,000	Guinea	260,000	Cuba	448,000
India	96,000	Guinea Bissau	243,000	Dominican Rep.	9.000
Indonesia	2,500,000	Gambia	60,000	El Salvador	36,000
Kampuchia	10,000	Kenya	45,000	Ecuador	196,000
Malaysia	674,000	Liberia	40,000	French Guiana	55,000
Pakistan	345,000	Mauritania	Few ha.	Guadeloupe	3,000
Papua New Guinea	553,000	Madaqascar	320,700	Guatemala	50,000
Philippines	240,000	Mozambique	85,000	Guiana	150,000
Sri Lanka	4,000	Senegal	440,000	Haiti	18,000
Thailand	288,000	Sierra Leone	100,000	Honduras	145,000
Vietnam	320,000	Nigeria	973,000	Jamaica	7,000
		Tanzania	96,000	Martinique	2,000
		Zaire	20,000	Mexico	660,000
				Nicaragua	60,000
				Panama	486,000
				Peru	28,000
				Surinam	115,000
				Trinidad & Tobago	4,000
				U.S.A. (Florida & P.Rico)	178,000
				Venezuela	260,000
TOTAL	**7,441,000**		**3,258,000**		**5,831,000**

GRAND TOTAL: 1,65,30,000 ha or 1,65,300 sq, kms.

Sources : (*) Wacharakitty (1983)
(**) Saenger *et al.*, (1983)
(***) FAO (1981)

According to Chapman (1970), a total of 55 mangrove species are known so far of which 44 are found in the Indian Ocean-Western Pacific Zone. A compilation by Saenager *et al.*, (1983) of the trees and shrubs of the world's mangroves gives the number of species as 60 including two palms *Nypa fruticans* and *Phoenix paludosa*. Duke (1992) and IUCN (1983) have reported total 70 species of mangroves all over the world and given information on family, distribution in six different geographical regions and structure in respect of each mangrove species (Table-1.6).

TABLE-1.6

WORLD DISTRIBUTION OF MANGROVE SPECIES

Family	Genus	Species	Struc -ture	Geographical Regions					
				1	2	3	4	5	6
Acanthaceae	*Acanthus*	*ebracteatus*	S					+	+
		ilicifolius	S					+	+
Arecaceae	*Nypa*	*fruticans*	P					+	+
Avicenniaceae	*Avicennia*	*germinans*	T	+	+	+			
		bicolor	T	+					
		schauerianna	T		+				
		marina	T				+	+	+
		alba	T					+	+
		rumphiana	T					+	+
		officinalis	T					+	+
		integra	T						+
Bignoniaceae	*Dolichandrone*	*spathacea*						+	+
Bombacaceae	*Camptostemon*	*philippinensis*	T					+	
		schultzii	T						+
Caesalpiniaceae	*Cynometra*	*iripa*	T					+	+
		ramiflora	T					+	
Combretataceae	*Conocarpus*	*erectus*	T	+	+	+			
	Laguncularia	*racemosa*	T	+	+	+			
	Lumnitzera	*racemosa*	S/T				+	+	+
		xrosea	S/T						+
		littorea	S/T					+	+
Euphorbiaceaea	*Excoecaria*	*agallocha*	T					+	+
		indica	T					+	
		avata	T						+
Lythraceae	*Pemphis*	*acidula*	S/T				+	+	+
Meliaceae	*Aglaia*	*cucullata*	T					+	
	Xylocarpus	*granatum*	T				+	+	+
		mekongensis	T					+	+
		moluccensis	T					+	+
Mvrsinaceae	*Argiceras*	*corniculatum*	S					+	+
		floridum	S					+	
Myrtaceae	*Osbornia*	*octodonta*	S					+	+
Pellicieraceae	*Pelliciera*	*rhizophorae*	T	+	+				
Plumbaginaceae	*Aegialitis*	*rotundifolia*						+	
		annulata						+	+
Pteridaceae	*Acrostichum*	*danaeifolium*	F	+	+				
		aureum	F	+	+	+	+	+	+
		speciosum	F					+	+
Rhizophoraceae	*Bruguiera*	*gymnorrhiza*	T				+	+	+
		sexanggula	T					+	+

		exaristata	T						+
		hainesii	T					+	+
		parviflora	T					+	+
		cylindrica	T					+	+
	Ceriops	*tagal*	T				+	+	+
		decandra	T					+	+
		australis	T						+
	Kandelia	*candel*	S/T					+	
	Rhizophora	*racemosa*	T	+	+	+			
		harrisonii	T	+	+	+			
		mangle	T	+	+	+			
		samoerisis	T						+
Rhizophoraceae	*Rhizophora*	*apiculata*	T					+	+
		mucronata	T				+	+	+
Rhizophoraceae	*Rhizophora*	*xlamarckii*	T					+	+
		stylosa	T					+	+
		xselala	T						+
Rubiaceae	*Scyphiphora*	*Hydrophyllacea*	S					+	+
Soneratiaceae	*Sonneratia*	*apetala*	T					+	
		griffithii	T					+	
		alba	T				+	+	+
		ovata	T					+	+
		caseolaris	T					+	+
		xurama	T						+
		xgalngai	T					+	+
		lanceolata	T					+	+
Sterculiaceae	*Heritiera*	*liitoralis*	T				+	+	+
		fomes	T					+	
		globosa	T					+	

Index: T- Tree, S- Shrub, P- Palm, and F-Fern
1- West America, 2- East America,
2- West Africa, 4- East Africa,
5- Indo- Malaysia, 6- Australasia.

SOURCE: Duke (1992), IUCN (1983)

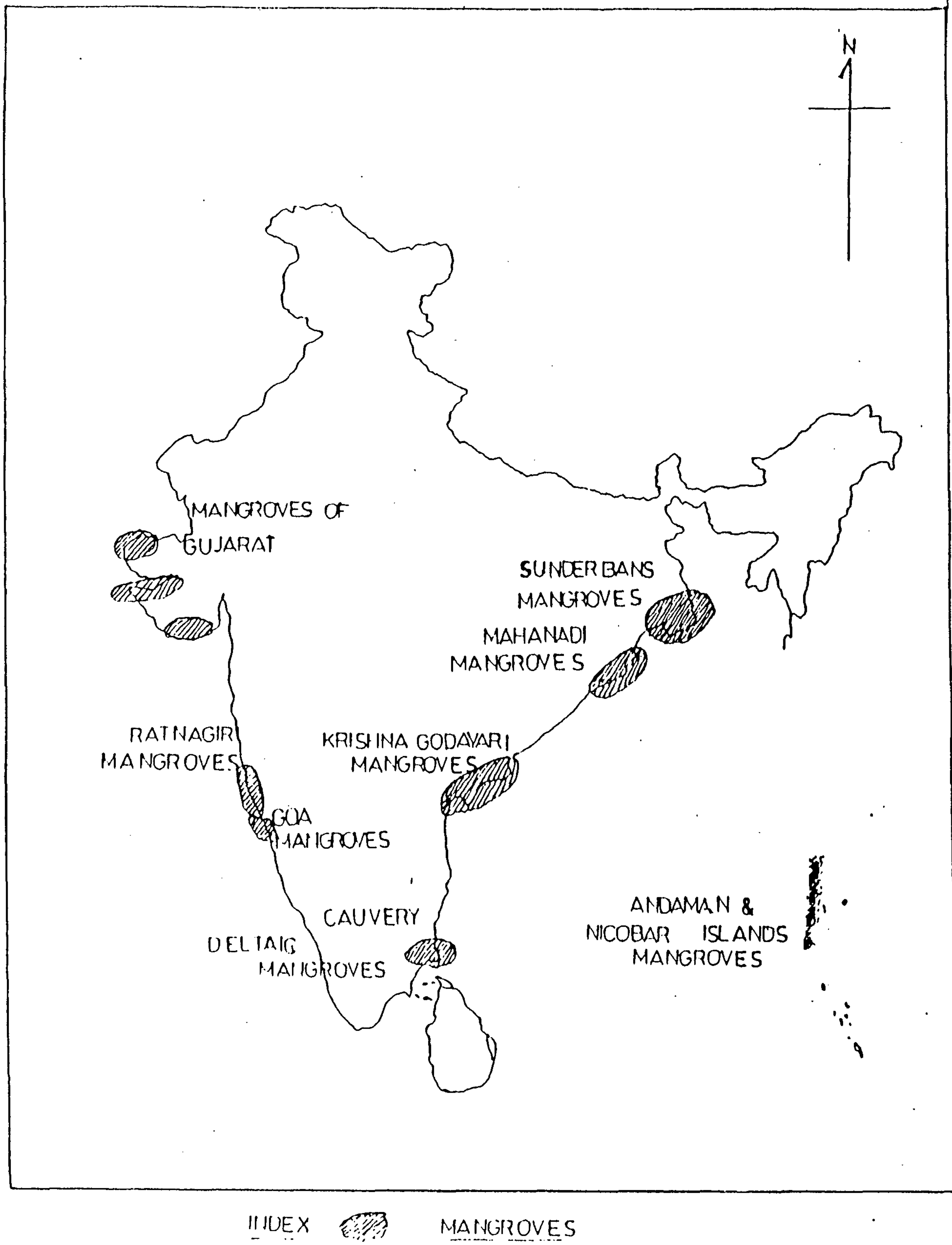


Figure-1.2 Mangroves sites in India

1.4.2. INDIAN SCENARIO

In India, mangroves occur on the West Coast, East Coast and Andaman and Nicobar Islands (Figure-1.2). Geographical area under mangroves in different State/ Union Territory is shown in Table-1.7. It shows the area reported by Govt. of India (1987), Indian Remote Sensing Data (Nayak, 1993) and Forest Survey of India (1997).

Indian mangroves are distributed in about 6,740 sq. kms (Krishnamurthy *et al.*, 1987) which constituted 7% of the world mangroves (Untawale, 1987). The area wise distribution of mangrove forests in India has been reviewed (Deshmukh, 1991). Status of mangroves along the Arabian Sea has been reviewed (Untawale *et al.*, 1992). There are three different types of mangroves in India *viz.*, deltaic, backwater-estuarine and insular categories. The deltaic mangroves occur on the east coast (Bay of Bengal) where the mighty rivers make the deltas. The backwater-estuarine type of mangroves exist in the west coast (Arabian) which is characterised by typical funnel-shaped estuaries of major rivers (Indus, Narmada and Tapti) or backwaters, creeks, and neritic inlets. The insular mangroves are present in Andaman & Nicobar Islands where many tidal estuaries, small rivers, neritic inlets, and lagoons support a rich mangrove flora (Gopal and Krishnamurthy, 1993).

TABLE-1.7

AREA WISE DISTRIBUTION OF MANGROVES IN INDIA

S.N.	State/ Union Territory	Area* (Sq. Kms.)	Area** (Sq. Kms.)	Area*** (Sq. Kms.)
1	West Bengal (Sunderbans)	4200	1619	2123
2	Andaman & Nicobar Islands	1190	770	966
3	Maharashtra	330	138	124
4	Gujarat	260	1166	991
5	Andhra Pradesh	200	480	383
6	Tamil Nadu	150	90	21
7	Orissa	150	187	211
8	Karnataka	60	19	3
9	Goa	200	5	5
10	Kerala	Sparse	Sparse	Nil
	TOTAL	**6740**	**4474**	**4827**

Note: The value of area has been rounded to the nearest 10 sq kms.

Sources:

* Status reports on mangroves in India, Govt. of India, Ministry of Environment and Forests, December 1987.

** Indian Remote Sensing Data (Nayak, 1993)

*** State of Forest Report, 1997; Forest Survey of India, Government of India.

Of the country's total area under the mangrove vegetation, 70% is recorded on the East Coast, and 12% on the West Coast. The Bay Islands (Andaman & Nicobar) account for 18% of the Country's total mangrove area (Krishnamurthy *et al.*, 1987; Kathiresan, 1995a). The mangrove have a vast existence on the east coast of India due to the nutrient rich alluvial soil formed by the rivers- Ganga, Brahmaputra, Mahanadi, Godavari, Krishna and Cauvery and a perennial supply of fresh water along the deltaic coast. But, the deltas with alluvial deposits are almost absent on the West Coast of India, only funnel-shaped estuaries or backwaters are present (Gopal and Krishnamurthy, 1993).

The Sunderbans in West Bengal has the largest area of 4,200 sq kms which forms the largest block of mangroves of the world, taken together with Bangladesh (Krishnamutrhy *et al.*, 1987).

Andaman and Nicobar Islands harbour a rich diversity of mangroves. Dense mangroves are found on these islands along the creeks, near bays and lagoons. Mangroves occupy an area of about 770 sq kms (RSAM, 1992). Further information on acreage of mangroves on these islands, is provided by Singh *et al.*, (1986), Rajagopalan (1987) and Dagar (1987). Mapping of mangroves has also been carried out on the Andamans and Nicobars by National Remote Sensing Agency (1988). Ranganath *et al.*, (1989) used satellite data to map mangrove distribution on eight islands (Havelock, Neal, Nicholson, Wilson, John Lawrence, Henry Lawrence, English and Outram Islands). Bagla and Menon (1989) gave a figure of around 66,261 ha of mangroves in the Andaman and Nicobar Islands.

The mangrove areas of South Andaman Islands have also been mapped through remote sensing (Krishnamoorthy *et al.*, 1993).

In Orissa, the mangroves are present on the Mahanadi delta, the Brahmani-Baitarani delta and along the Balasore coast with dominant species - *Avicennia* species, *Rhizophora mucronata, Excoecaria agallocha, Ceriops roxburghiana* etc. (RSAM, 1992). The mangroves near the mouth of the Mahanadi River form a creek network of the Luna, the Jambu, the Kharnasi, the Khola and the Batighar jora creeks. The creeks are arranged parallel to the coast, inundated by daily tides. The Bhitarkanika mangroves are luxuriant due to the beneficial influence exerted by the Brahmani and the Baitarani Rivers and their distributaries and creeks upon the terrain.

In Andhra Pradesh, dense mangrove vegetation is found towards the coast rather than on shoreland because of the network of creeks, which exist towards the coast (RSAM, 1992). There is more mangrove vegetation on tidal flats on the western side of the Krishna delta than on its eastern side. Dense mangroves are also seen over recent sand/mud spits on the Nizampatnam bay (RSAM, 1992). Sparse mangroves are found on the eastern side of the Krishna delta.

Mangroves in Tamil Nadu exist on the Cauvery deltaic areas. Pichavaram has well developed mangrove forest dominant with *Rhizophora* species, *Avicennia marina, Excoecaria agallocha, Bruguiera cylindrica, Lumnitzera racemosa, Ceriops decandra* and *Aegiceras corniculatum*. Mangroves also occur near Vedarnyam, Kodiakarai (Point Calimere), Muthupet, Chatram and Tuticorin.

The good mangrove cover in the Rann of Kutch (Gujarat) exist along the Kori creek (RSAM, 1992). In the Gulf of Kutch, dense mangroves are observed around the Patre creek, the Dide kabet, Valsura, Navlakhi and near Mundra jetty. Patches of sparse mangroves are observed near Okha, Poshitra, Pindhara, Dhani, Narara, Sikka, Jindra, Pirotan, and near the Jakhau port (RSAM, 1992). The mangrove species- *Avicennia marina* and *Rhizophora mucronata*- dominate in the Gulf of Kutch. On Saurashtra coast, mangroves occur only in very sparse patches along the creeks on the intertidal mud flats along the Jafrabad creek and the Buthrani creek. In the Gulf of Khambhat, degraded mangroves are seen along the coast near the Mahi, the Dhadhar, the Narmada, the Kim and the Sena rivers. A small patch of dense mangroves is found on the Kolak estuary and a small creek near Umargam. On the Konai creek, mangroves are present scattered (RSAM, 1992).

In Maharashtra, good mangroves exist along the Vasisthi estuary, the Savithri estuary, the Kundalika estuary, the Dharamtar creek, the Panvel creek, the Vasai creek, the Thane creek and the Vaitarana creek (RSAM, 1992).

In Goa mangroves occur along its seven estuaries and Cumbarjua canal (Untawale *et al.*, 1982).

Mangroves of Karnataka cover an area of 6,000 ha, of which 1,000 ha are in Uttara Kannada district alone. About 14 species belonging to nine genera are extensively distributed in the district. The mangrove forest occurs along the northern coast of Karnataka, in the Kalinadi, Gangivali and Agnachini estuaries and at the confluence of the Chakra Nadi, Kollur and Haladi Rivers near Gangolli

(Parnetta, 1993). In general, the mangroves are only sparsely distributed along the Karnataka coast.

Distribution of mangroves in Kerala has been described by Basha (1991). It was stretching for about 1,000 sq kms, a century ago, but is now reduced to just about 17 sq kms in isolated bits at Kumaragom, Dharmadom, Chettuva, Nadakavu, Pappinisseri, Kunjimangalam, Chateri, Veli etc.

Mangrove species found in India along East Coast, West Coast and Andaman & Nicobar Islands have been listed in Table-1.8.

TABLE-1.8

DISTRIBUTION OF MANGROVE SPECIES IN INDIA

Family	**Genus**	**Species**	**East coast**	**West coast**	**A & N Islands**
Acanthaceae	*Acanthus*	*ebracteatus*			+
		ilicifolius	+	+	+
		volubilis	+		+
Arecaceae	*Nypa*	*fruticans*	+		+
	Phoenix	*paludosa*	+		+
Avicenniaceae	*Avicennia*	*marina*	+	+	+
		alba	+	+	
		officinalis	+	+	+
Bignoniaceae	*Dolichandrone*	*spathacea*	+	+	(+)
Caesalpiniaceae	*Cynometra*	*iripa*			(+)
		ramiflora			+
Combretataceae	*Lumnitzera*	*racemosa*	+	+	+
		littorea			+
Euphorbiaceaea	*Excoecaria*	*agallocha*	+	+	+
Meliaceae	*Aglaia*	*cucullata*	+		
	Xylocarpus	*granatum*	+		+
		mekongensis	+		+
		moluccensis			+
Myrsinaceae	*Aegiceras*	*corniculatum*	+	+	+
Plumbaginaceae	*Aegialitis*	*rotundifolia*	+		(+)
Pteridaceae	*Acrostichum*	*aureum*	+	+	+
		speciosum			(+)

Rhizophoraceae	*Bruguiera*	*gymnorrhiza* *sexangula* *parviflora* *cylindrica*	+ + + +	+ +	+ + + +
	Ceriops	*tagal* *decandra*	+ +	+ +	+ (+)
	Kandelia	*candel*	+	+	(+)
Rhizophoraceae	*Rhizophora*	*apiculata* *mucronata* *lamarckii* *stylosa*	+ + +	+ + 	+ + + +
Rubiaceae	*Scyphiphora*	*hydrophyllacea*	+		+
Soneratiaceae	*Sonneratia*	*apetala* *griffithii* *alba* *caseolaris*	+ + +	 + +	+ (+) +
Sterculiaceae	*Heritiera*	*littoralis* *fomes*	+ +	+	+

INDEX:
+ = Presence

(+) = Present in Andaman and Nicobar Islands but not in Middle Andaman

SOURCE: Banerjee and Gosh (1998) & Dagar *et al.*, (1991)

1.5. MANGROVE CONSERVATION AND MANAGEMENT SCENARIO AROUND THE GLOBE WITH SPECIAL REFERENCE TO INDIA

Today, the world community has recognised and realized the significance of mangrove ecosystem. Almost all the countries in the world with mangroves have their own mangrove conservation and management plans matching with their geographical location, priorities and needs. Many countries have given special emphasis on restoration of degraded mangrove areas by taking artificial regeneration of mangroves. Among such few countries are Australia, Thailand, Malaysia, Vietnam, Indonesia, India, Pakistan, Bangladesh, United States of America, Cuba, Colombia, Panama etc (Field, 1996).

Apart from the efforts made by the individual countries towards conservation and management of mangroves, several international organizations have come up to promote and coordinate the efforts being made in different parts of the world. Few of them are International Society for Mangrove Ecosystem (ISME), Food and Agriculture Organisation (FAO) of the United Nations and Mangrove Action Project (MAP).

International Society for Mangrove Ecosystem (ISME) based at Okinawa, Japan aims at creating a well-organised network of scientists, managers, planners, decision makers and all person interested in all aspects of mangrove studies and management.

Forestry department of **Food and Agriculture Organisation (FAO)** of United Nations (UN) with it's headquarters at Rome (Italy) alone and in co-operation with the other UN agencies has promoted seminars and workshops on mangrove management in Central America, the Carribean, West Africa and the Asia Pacific region. Through technical co-operation programme, integrated forest models have been developed for Cuba, Costa Rica, Vietnam and many other countries. FAO has also provided technical expertise in mangrove management to assist countries such as Panama, Guyana, Ecuador, Sierra Leone, Kenya, Bangladesh, Myanmar, Thailand, Indonesia, Papua New Guinea etc.

United Nations convened a meeting during 1997 to review the progress made in implementing **"Agenda 21"** emerged from the **"EARTH SUMMIT"** held during June 3-14, 1992 in Rio De Janeiro, Brazil. The Agenda 21 includes some of the items related to the conservation and management of mangroves such as protection of coastal areas, their rational use, development of their living resources and conservation of biological diversity.

Mangrove Action Plan (MAP), based in Seattle, in western United States is an international network on mangrove forests, which includes more than 300 non-governmental organizations and some 200 scientists from nearly 50 countries.

During the British rule in India, Mangroves were not given due importance and there was no scientific management of these forests except timber extraction management plan for Sunderbans. Due to immense biotic interference and multiple uses of mangrove vegetation, this resource is threatened with great destruction. In India, there is severe pressure for the conversion of mangrove areas to agriculture, industries, aquaculture and upstream river water diversion for irrigation or other purposes. These factors are severely disturbing mangroves ecosystem by diminishing fresh water inflows, increasing soil salinity and interfering with nutrient supply. If this destruction is not checked, mangroves may get completely wiped out with a short span of time.

During 1976, a set of ten Fundamental Duties for Indian citizens was incorporated in the Indian Constitution by way of 42nd amendment. It, *inter alia,* says that it shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures. This clearly shows concern of the Government of India for the conservation of forests and wild life. However, recognizing the importance of the mangroves, the Govt. of India (Department of Science and Technology) set up the **National Mangrove Committee** on the mangrove ecosystems. The first meeting of the group was held on 12th October 1976 at the National Institute of Oceanography at Panaji, Goa. One of the very first recommendations of the panel was to emphasize the need to conduct a survey of actual mangrove areas within the country with regard to their extent. Realizing the gravity of the situation the Govt. of India have introduced a scheme for the conservation and protection of this precious ecosystem. The strategy consists of :

A) Identification of selected mangrove areas for conservation.

B) Preparation of Management Plan.

C) Promotion of Research.

I) Adoption of a multi- disciplinary approach involving the State Governments, Universities, and research institutions and local organizations.

Recommendation of National Mangrove Committee (1979)

A National Mangrove Committee was set up in the Ministry of Environment and Forests for the conservation and development of mangrove ecosystem. The Committee consists of Scientists, Research scholars and experts of mangrove ecosystems. The committee recommended the following areas for research and development as well as management for mangrove environment.

a) Nationwide mapping of the mangrove areas, preferably by Remote Sensing techniques coupled with land surveys. Time series should be obtained to make an assessment of the rate of degradation of the ecosystems.

b) The mangrove forests should be surveyed quantitatively for area, climatic regime, and rate of growth of forest trees and seasonal variations of environmental parameters.

c) 1. Assessment of suitable sites for the "Reserve Forests".

2. Conservation programmes.

d) Afforestation of degraded mangrove areas.

e) Research activities in mangrove ecosystem.

f) Management of mangrove forests.

g) Ecology of mangroves.

h) Floral and faunal components.

i) Microbiological role.

j) Qualitative and quantitative studies for organic production.

k) Biochemistry of organic matter and sediments.

The committee is meant to advise the Government of India on various steps required for the Conservation and Management of mangroves in India. At one of the subsequent meetings held under the Chairmanship of the Secretary, Department of Environment in the year 1982, it was decided to gather all available information and particular on the research conducted within the country on this ecosystem. Under the guidance of the Government of India, various States and Union Territories have prepared Management Action Plans for conservation and development of mangrove ecosystem. Government of India is also providing financial assistance to the States and Union Territories for implementation of Mangrove Management Action Plans. Government of India has also taken up research on various aspects of mangroves through reputed academic institution with a view to provide inputs for development of mangrove ecosystems on sound ecological basis.

On the basis of the National Mangrove Committee's recommendation, 15 mangrove areas were identified for conservation and preparation of Management Action Plans. The selected mangrove areas include: Coastal Goa (Goa), Goringa, Godavari delta and Krishna Estuary (Andhra Pradesh), Gulf of Kutch (Gujarat), Goondapur (Karnataka), Vemband (Kerala), Achra/Ratnagiri (Maharashtra), Mahanadi delta and Bhitarkanika (Orissa), Pichavaram and Point Calimere (Tamilnadu), Sundarbans (West Bengal), North Andaman & Nicobar (Andaman and Nicobar Islands). Most of the States/Union territories have already finalised their Mangrove Management Action Plans, which are being implemented. The plans broadly cover survey and demarcation, natural regeneration in selected areas, afforestation, protection measures such as watch and ward, fencing etc. and awareness programmes.

Mangroves and National Forest Policy, 1988.

National Forest Policy, 1988 does not specifically mention about conservation of mangroves but its basic objectives and priority areas in the field of forestry research clearly relates to conservation of mangroves. Following are the basic objectives of the National forest Policy, 1988, which are relevant to conservation and management of mangroves.

1. Maintenance of environmental stability through preservation and where necessary restorations of the ecological balance that has been adversely disturbed by serious depletion of the forests of the country. The National forest policy, 1988 has made it very clear that while managing a forest, environmental benefits will have priority over the economic benefits. It says, "the principal aim of forest policy must be to ensure environmental stability and maintenance of ecological balance including atmospheric equilibrium which are vital for sustenance of all life form human, animal and plant. The derivation of direct economic benefit must be subordinated to this principal aim".
2. Conserve the natural heritage of the country by preserving the remaining natural forests with the vast variety of flora and fauna, which represent the remarkable biological diversity and genetic resources of the country.
3. Checking soil erosion.

4. Increasing tree cover through massive afforestation and social forestry programmes especially on all denuded, degraded and unproductive lands.

5. Meeting the requirement of fuelwood, fodder, MFP (Minor Forest Produce) and small timber of the rural and tribal population.

6. Increasing productivity of the forest to meet essential national needs.

7. People's involvement (including women) for achieving objectives.

As government agencies have limited financial, human and other resources, people's involvement is essential for proper management of geographically scattered mangrove resources.

8. Priority areas in forestry research.

The National Forest Policy, 1988 has listed some priority areas in the field of forestry research. One such priority area is **"Effective conservation and Management of existing forests (Mainly Natural Forest Eco-system)"**. Thus, it is very clear that research in the field of conservation and management of mangrove eco-system is a national priority.

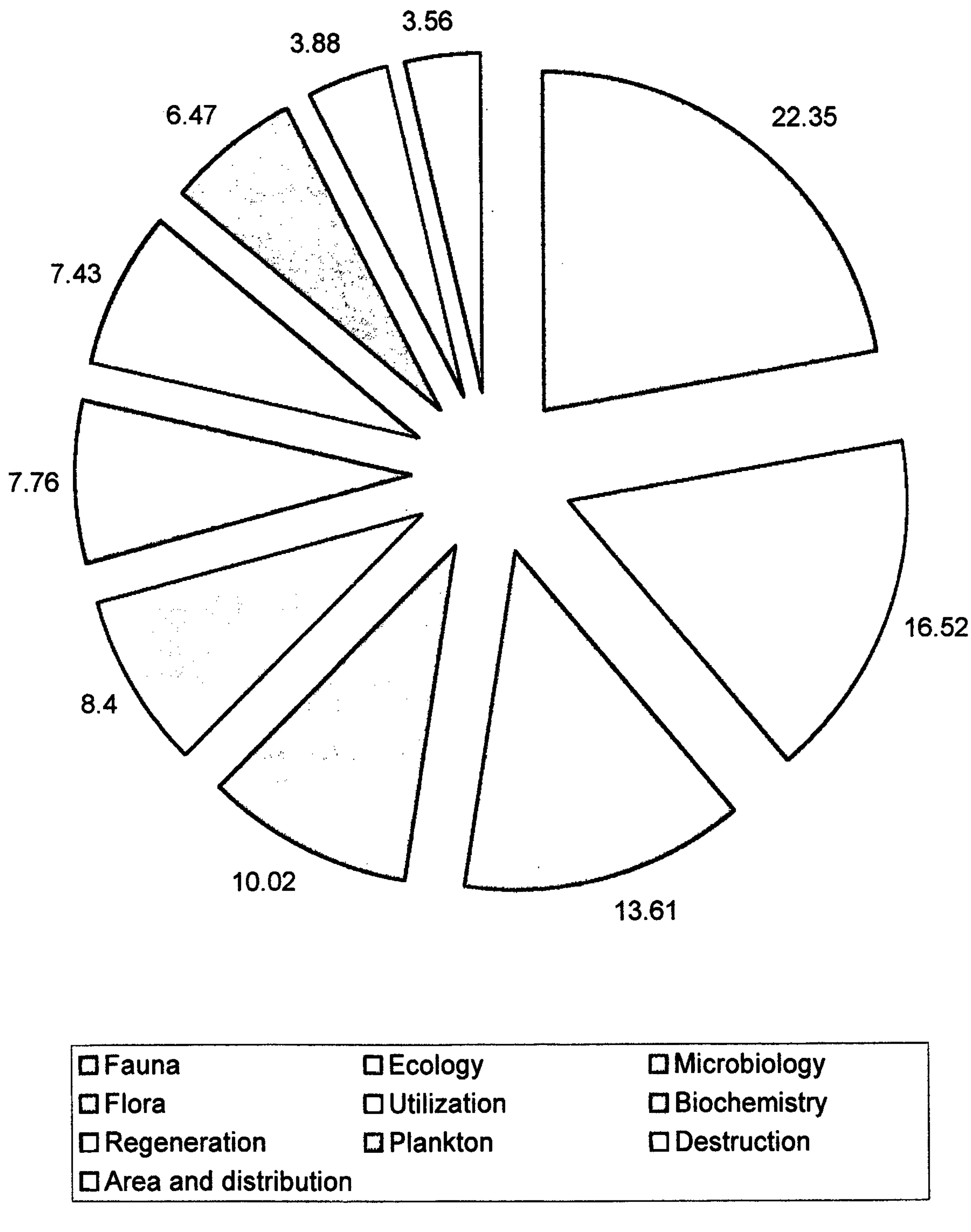


Figure- 1.3 Percentage of research papers published for Indian mangroves from 1987 to 1996

1.6. JUSTIFICATION OF THE PROBLEM

Increasing human pressure on the limited mangrove resources due to increase in population, increasing awareness regarding environmental and economic use of mangroves has highlighted the need for mangrove conservation and management. For preparing appropriate and effective management plan basic data and information are required. In many countries, much of the basic information needed for development and execution of management plans in mangrove forests, is presently not available (FAO, 1994).

Over 300 research papers concerned with Indian mangroves have been published in a period of 10 years from 1987- 1996 (Anonymous, 1997; Figure- 1.3) Fauna, flora, ecology and microbiology aspects have been well- studied as evident by the publications of over 60% of total research papers. However, some key aspects of mangrove conservation and management like regeneration, area and distribution etc have received poor attention. Through the present study an effort has been made to collect information on these key aspects.

The study was carried out in State of Goa and Middle Andaman Forest Division comprising of various islands. During the study lot of information, directly or indirectly related to conservation and management of mangroves, was collected from both the study areas which offers opportunity for comparison of the results. The study has got special significance as it was conducted in two entirely different regions in following respects-

(a) State of Goa is a part of Indian mainland while another area of study i.e. Middle Andaman Forest Division comprises of several islands.

(b) State of Goa is located on the West Coast while Andaman Islands are located off East Coast of India.

(c) State of Goa is located adjoining to the Arabian Sea while Andaman Islands are located in the Bay of Bengal. Geographically these two areas are different.

(d) These two areas are geologically and ecologically different.

(e) Socio-economic scenario is different in these two areas. People's needs and priorities are different.

(f) There are differences in the mangrove resources of these two areas. As their status, local needs, and problems are different, many of the conservation and management practices are bound to be different.

Conservation and Management of mangroves is a vast and relatively new subject. According to Indian National Forest Policy, 1988, the word "Conservation" includes preservation, maintenance, sustainable utilization, restoration and enhancement of natural environment. Mangrove management is a powerful tool to control the various aspects of mangrove conservation to achieve the desired results. But, to have an appropriate Management Plan, we must have a broad and authentic database and information derived from the management research, to cater to the need of the managers. The database and information help in knowing ecological and people's needs of a particular locality and to evolve a strategy to keep a balance between ecological and people's needs. It is utmost important to involve local people residing close to mangrove belts in mangrove management programme by educating them and fulfilling their genuine demand of minor forest produce from the mangrove forests. For this purpose, we must have the information on the actual extent of mangrove areas and its growing stock to plan sustainable resource utilization. This information has also been collected through the present study.

Mangroves are endangered by hostile habitat and human abuse (Kathiresan, 1995a). Our country has lost 40% of the mangrove area of what existed a century ago (Krishnamurthy *et al.*, 1987). The National Remote Sensing Agency (NRSA) has recorded a decline of 7000 ha of mangroves in India within six- year period from 1975 to 1981. If the trend is not reversed, mangroves will get completely wiped out from our country (Kathiresan, 1995a). Mangrove destruction in Andaman and Nicobar Islands has been reported by Bagla and Menon (1989) stating that about 10,000 ha area have been cut since 1960, mainly for the fuelwood. There are several such reports coming from various parts of the globe. The need of the hour is to take urgent action to protect and restore mangrove forests. One very important aspect of management of mangrove is its artificial regeneration in various degraded areas. As this is a relatively new subject, there is urgent need to standardize the nursery and plantation techniques for various mangrove species. For the Biodiversity Conservation, we must know about the status of natural regeneration of various species so that the rare and threatened species may be timely saved by taking appropriate actions. All these aspects have been dealt in the present study. Results obtained from the study will definitely help scientists, managers, bureaucrats, non-governmental organizations etc. in their endeavor for conservation and management of mangroves.

CHAPTER-2

MANGROVES OF GOA

CHAPTER-2

MANGROVES OF GOA

2.1. INTRODUCTION

2.1.1. GENERAL DESCRIPTION

Goa is a small state situated along the central western coast of India. It is located between latitudes 15°48'00" N and 14°53'54" N and longitude 74°20'13" E and 73°40'33" E. Its geographical area is 3702 sq. kms. Its altitude ranges from sea level to 1022 meters. Goa is bounded on the North by Sindhudurg district of Maharashtra, on the East by Belgaum district of Karnataka, on the South by Karwar district of Karnataka and on the West by the Arabian Sea.

Population of Goa according to 1991 census is 11,69,793 (Table-2.1). It can be seen that population of Goa has risen sharply after 1960 and during 1971 census population increased by 34.77%. Similarly, during 1981 and 1991 census population of Goa increased by 26.74% and 16.08% respectively. Increase in population is an important factor in mangrove management as human pressure on forest increases with the increase in population.

Goa has 120 kms long coast line. Seven estuaries of Goa namely Terekhol, Chapora, Mandovi, Zuari, Sal, Talpona, and Galgibag are navigable throughout the year (Figure-2.1). These estuaries originate in the Sahyadri ranges of Western Ghats. The estuaries flow westward and join the Arabian Sea. Mangroves occur along the seven estuaries and Cumbarjua canal. Untawale *et al.*, (1982) estimated the mangrove area in Goa as 2000 ha using aerial photographs. (Table-2.2)

TABLE-2.1

GROWTH OF POPULATION IN GOA

S.No.	Year	Number of persons	Percentage variation
1	1900	4,75,513	-
2	1910	4,86,752	+ 2.36
3	1921	4,69,494	- 3.55
4	1931	5,05,281	+ 7.62
5	1940	5,40,925	+ 7.05
6	1950	5,47,448	+ 1.21
7	1960	5,89,997	+ 7.77
8	1971	7,95,120	+ 34.77
9	1981	10,07,749	+ 26.74
10	1991	11,69,793	+ 16.08

SOURCE: Directorate of Planning, Statistics & Evaluation, Govt. of Goa

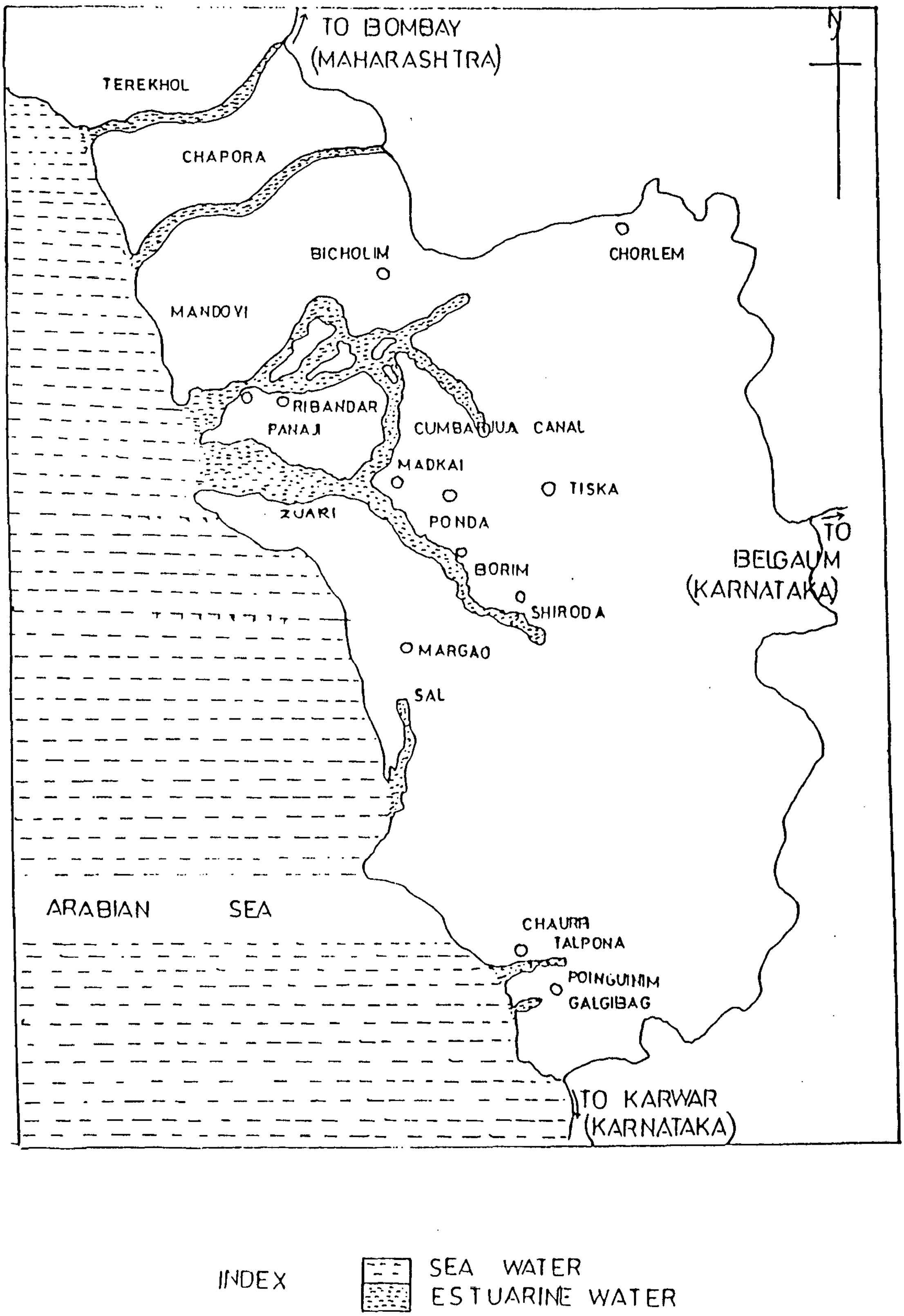


Figure-2.1 Mangroves bearing estuaries and canal in Goa

TABLE-2.2

MANGROVE AREA ALONG VARIOUS ESTUARIES IN GOA

S.N.	Estuary	Estuary length (kms)	Estuary area (ha)	Mangrove area (ha)	Mangrove %
1	Terekhol	26	349	30	8.6
2	Chapora	30	711	100	14.0
3	Mandovi	68	5564	700	12.6
4	Zuari	63	5790	900	15.5
5	Cumbarjua canal	15	375	200	53.3
6	Sal	10	302	30	9.9
7	Talpona	9	40	20	50.0
8	Galgibag	16	26	20	76.9
	TOTAL	**237**	**13157**	**2000**	**15.1**

SOURCE: Untawale *et al.*, (1982)

2.1.2. COASTAL GEOMORPHOLOGY

The peculiar feature of Goa region is that by the side of the Western Ghat mountain range, there is a flat plain of about 20 to 60 kms. Most of the rivers flow through the sunken parts, or the valleys, of this plain to meet the Arabian Sea. The gradient of mountains is steep, while the slopes of the estuaries are gentle where the mangroves are located. These peculiar geographical formations result into the fringing mangroves along the estuaries and creeks. The delta formations which are normally observed along the plains of the East Coast of India are absent although estuarine submerged mud banks are formed in some parts.

2.1.3. CLIMATOLOGY

The central West Coast of India is a tropical region, parallel to the Western Ghat Mountains where monsoonal precipitation during June to September is maximum. There are three seasons normally divided into monsoon, post-monsoon and pre-monsoon. The average rainfall in the catchment areas is from 3,000 mm to 3,500 mm per year, while in the coastal region it varies from 2,000 mm to 3,000 mm per year. Rainfall varies from West to East. Coastal stations like Panjim and Marmagao record annual rainfall of 2750 mm. The air temperature fluctuates between 21°C and 32°C depending on the season. The mean wind speed is between 5 to 10 knots. Average climatological data for Marmagao (Goa) has been shown in Table-2.3. Unlike the East Coast, the central West Coast of India rarely experiences any cyclonic storms, however, details of depressions or cyclonic storms that affected Goa coast are listed in Table-2.4.

TABLE-2.3

AVERAGE CLIMATOLOGICAL CONDITIONS AT MARMAGAO (GOA)

Month	Pressure at M.S.L. (mb)	Air temperature Daily Max °C	Air temperature Daily Min °C	Relative Humidity 0800 hrs. %	Relative Humidity 1700 hrs. %	Average rainfall mm	Mean wind speed knots	Hours of Sunshine
January	1013	30	21	66	61	2	6	309
February	1012	29	22	73	66	1	6	294
March	1011	30	24	74	68	1	7	297
April	1009	31	26	75	59	19	7	290
May	1008	32	26	77	72	67	8	288
June	1007	30	25	85	83	752	9	122
July	1007	28	24	87	86	794	10	99
August	1008	28	24	85	86	403	9	99
September	1009	28	23	84	83	240	7	177
October	1010	30	24	83	77	96	6	253
November	1011	31	23	69	64	33	5	274
December	1013	30	22	63	60	6	6	295

SOURCE: Meteorological Department, Government of Goa.

TABLE-2.4

DETAILS OF DEPRESSIONS/CYCLONIC STORMS THAT AFFECTED GOA COAST

S.N.	Date/Year/Month	Type	Remarks
1.	9-12th October, 1921	Depression	Moved across the interior peninsula and crossed Goa as depression and emerged into Arabian Sea.
2.	8-16th October, 1958	Depression	Moved across peninsula and crossed Goa coast on 8^{th} October as a depression.
3.	24-25th May, 1961	Severe cyclonic storm (SCS)	Crossed coast between Devagadh and Ratnagiri as a SCS. The worst affected areas were Sawantwadi, Vengurla, Malwan and Kudal.
4.	13-14th November, 1966	SCS	Crossed coast near Ratnagiri.
5.	5th June 1994	Depression	Depression off Goa coast moved away in North Westerly direction.

SOURCE: Meteorological Department, Government of GOA

2.1.4. HYDROLOGY

The estuaries of Goa originate in the Sahydri ranges of Western Ghats and flow westward to join the Arabian Sea. Water of the sea enters in the estuaries during high tide from the western side while the estuaries receive fresh water throughout the year from the Western Ghat located on the eastern side of Goa. During the rainy season large quantity of water comes in the estuary from the Western Ghats and other parts of the land. Due to this peculiar situation, salinity of water in an estuary gradually reduces as we move towards upstream region. Change of mangrove species with the change of salinity can be conspicuously seen along the estuary.

2.1.5. TIDAL AMPLITUDE

The tides along the central West Coast of India are of semi-diurnal nature. The tidal amplitude, however, shows minor variation (Table-2.5).

TABLE-2.5

TIDAL AMPLITUDE ALONG CENTRAL WEST COAST OF INDIA

Stations	Lat.	Long	Height in metre above datum				
	N	E	MHHW	MLHW	MHLW	MLLW	MSL
Marmagao	15°24'	78°48'	2.02	1.76	1.00	0.38	1.29

SOURCE: Meteorological Department, Government of Goa.

2.1.6. EDAPHIC FACTORS

Mangrove stands are best developed along deltaic coasts or in estuaries where soft mud comprised of fine silt and clay and rich in organic matter is available for growth of seedlings. Quartzitic and granitic alluvial are poor substrata, whereas volcanic soils are highly productive for mangroves (Macnae, 1968). According to the nature of the substratum, mangroves may be classified as reef, sand, mud and peat type (Rutzler, 1969), and some may be found occasionally among boulders. The sedimentation in mangroves is both of allochthonous and autochthonous origin. In most of the swamps, river-borne sediments are the greatest source of allochthonous material, but in those mangrove swamps, which are not greatly influenced by fresh water flow, sedimentation of autochthonous matter becomes an important factor.

The soil of Goa may be broadly classified into three main types:

(1) Laterites of high and low level type formed by natural metamorphosis and degeneration of underlying rocks along the ghats.

(2) Red gravely soil derived from micaceous granite gneiss, covering the undulating plateau mixed with medium black soil adjoining riverbanks.

(3) Alluvial soils including coastal alluvium along the coastal belt and in low-lying situations.

2.2. MATERIAL AND METHODS

All the mangrove areas along the estuaries were studied thoroughly right from the upstream to mouth region. Intensive and extensive ground truthing was the cardinal principle throughout the study.

To study distribution of mangroves, one representative sample plot of one hectare area was laid down in each salinity zone and total number of mangrove plants were recorded. In case of Cumbarjua canal salinity zones are not so conspicuous as it joins Mandovi and Zuari estuaries. However, four representative sample plots of one-hectare area each were laid down along this canal at a regular interval to study mangrove vegetation. Based on the study, mangrove species were categorised as **Dominant, Common,** and **Rare** depending on the number of established plants found in various sample plots along an estuary. If more than 50 established plants were found in atleast any one the four sample plots along an estuary, it was categorised as Dominant species. Similarly, if the number was found falling within the class intervals 50-25 or 24-1, it was categorised as Common or Rare species respectively.

Natural regeneration in mangrove forest occurs in the form of plants of varying heights, which increase with age. A mangrove plant above 90 cms height can be considered as well established regenerating plant. To conduct regeneration survey along estuary 8 representative sample plots of the size 1000 sq mts (250m X 4 m) were selected at four different locations to cover all the species and their associations. At each of the four locations, two sample plots were laid down, one each in the Waterfront Zone and Landward Zone. Longer centre line of the linear plots was assumed as a transact and quadrants of 4 sq mts (2m X 2 m) size were laid down on the left and right side of the central line at an interval of 5 m. Thus, a total of 35 quadrants were laid down in each plot, and 100 % enumeration of seedlings/ saplings was done in each quadrant. These seedlings were divided into four different height classes viz. 0-30 cms, 31-60 cms, 61-90 cms and 91-120 cms and data were recorded accordingly. Same exercise was repeated along all the estuaries. Natural regeneration of a species along an estuary was considered Good if its minimum three seedlings were found present in each of the four height classes in atleast one sample plot. Similarly natural regeneration of a species was considered Moderate if its minimum two seedlings were found present in atleast any three of the four height classes, in atleast one sample plot. All other categories of natural regeneration were put under Poor.

For *Acanthus ilicifolius* and *Acrostichum aureum*, number of plants in 0-30 cms height class only were considered for judging the state of natural regeneration as the height of the mature plant in the above species seldom exceeds 60 cms. For *Derris heterophyllà* also number of plants in 0-30 cms height class only were considered for judging the state of natural regeneration. In respect of these three species, natural regeneration of a species is considered Good if minimum 6 number of seedlings were found present in at least one sample plot. Similarly natural regeneration of a species was considered Moderate if its 4-5 seedlings were found present in at least one sample plot. All other categories of natural regeneration were put under Poor. Same criteria was adopted while assessing the state of natural regeneration at various localities along an estuary.

2.3. RESULTS

There were conspicuous changes in the mangrove vegetation with the change of salinity of water. Water salinity was minimum in the upstream region where fresh water influence was highest. Water salinity increased gradually towards the mouth region of the estuary. Salinity was highest at the mouth region due to its proximity with the sea .In order to cover different type of mangrove vegetation in different salinity zones, the entire mangrove area was divided into four salinity zones viz. Polyhaline, Mesohaline, Oligohaline and Limnatic. Polyhaline zone was that zone where mangrove vegetation was first seen while moving from mouth region towards upstream region of the estuary. In Polyhaline zone the water salinity ranges from 30-18 ppt. Similarly, Limnatic zone was that zone where the mangrove vegetation was last seen while moving in the same direction. In Limnatic zone the water salinity is around 0.5 ppt. The remaining two salinity zones viz. Mesohaline and Oligohaline were located between the two extreme salinity zones and the water salinity ranged from 18-5 ppt and 5-0.5 ppt respectively in these two salinity zones.

2.3.1. Terekhol Estuary

The Terekhol estuary is about 26 kms in length. This estuary separates Goa from Maharashtra. Sample plot in Polyhaline zone was located near Keri, which was close to the mouth of the estuary. *Ceriops tagal, Avicennia officinalis, Rhizophora mucronata, Sonneratia alba* were the main mangrove species in this area. Few plants of *Avicennia marina* were also noticed. Most important characteristics of this plot was that there was a large concentration of *Ceriops tagal* plants which were not present elsewhere in Goa even in other parts of Terekhol estuary. Sample plot in Mesohaline zone was selected at Kiranpani, which was further upstream side. In this locality *Sonneratia alba* and *Rhizophora mucronata* were the main species while other mangrove such as *Avicennia officinalis, Excoecaria agallocha* were also present. Sample plot in Oligohaline zone was located near Naibaga. *Avicennia officinalis* and *Rhizophora mucronata* were the main species while other important species like *Sonneratia caseolaris, Kandelia candel* and *Excoecaria agallocha* were also present. Beyond Naibaga water salinity was low and mangrove vegetation occur in the form of scattered patches and isolated trees. Sample plot in Limnatic zone was selected near Konkan Railway Corporation's railway line. Mangrove species in this sample plot were *Excoecaria agallocha, Kandelia candel, Sonneratia caseolaris, Avicennia officinalis, Acanthus ilicifolius, Derris heterophylla* and *Acrostichum aureum.* Detailed results of sample survey are shown in Table-2.6.

Results of natural regeneration survey along Terekhol estuary have been shown in Table-2.7. At Keri (Polyhaline zone), *Avicennia officinalis* and *Ceriops tagal* were showing good natural regeneration. *Rhizophora mucronata, Avicennia marina, Sonneratia alba, Excoecaria agallocha* and *Derris heterophylla* had poor regeneration while regeneration in other species was absent.

At Kiranpani (Mesohaline zone), good regeneration was noticed in *Rhizophora mucronata*, *Avicennia officinalis* and *Sonneratia alba* while *Excoecaria agallocha* and *Acanthus ilicifolius* showed moderate regeneration. Renewal of crop in respect of *Rhizophora mucronata, Avicennia marina, Sonneratia alba, Aegiceras corniculatum* and *Derris heterophylla* was poor.

At Naibaga (Oligohaline zone), *Rhizophora mucronata* and *Avicennia officinalis* showed good regeneration. Moderate growth was found in *Acrostichum aureum.* On the other hand *Sonneratia alba, S. caseolaris, Kandelia candel, Excoecaria agallocha, Acanthus ilicifolius* and *Derris heterophylla* showed poor regeneration while in other species it was absent.

Near Konkan Railway Corporation's Railway line (Limnatic zone), only *Acrostichum aureum* was growing luxuriantly. Comparatively low regeneration was found in *Excoecaria agallocha, Aegiceras corniculatum*, *Acanthus ilicifolius* and *Derris heterophylla.*

Figure-2.2 shows overall natural regeneration pattern of mangroves (all species taken together) along Terekhol estuary. The study showed that with the increase in height of plants their number decreased. Competition among the plants for food, light and space etc. resulted in mortality of many mangrove species, which were not best fitted in the prevailing environment.

TABLE-2.6

MANGROVES IN VARIOUS SALINITY ZONES ALONG TEREKHOL ESTUARY

S.N	Species	Trees per ha. at **Keri** Polyhaline zone	Trees per ha. at **Kiranpani** Mesohaline zone	Trees per ha. near **Naibaga** Oligohaline zone	Trees per ha. near **KRC Railway line** Limnetic zone
1	*Rhizophora mucronata*	20	75	73	2
2	*Rhizophora apiculata*	-	-	-	-
3	*Avicennia officinalis*	30	24	108	4
4	*Avicennia marina*	7	-	-	-
5	*Avicennia alba*	-	-	-	-
6	*Sonneratia alba*	14	79	-	-
7	*Sonneratia caseolaris*	-	-	10	1
8	*Bruguiera gymnorrhiza*	-	-	-	-
9	*Bruguiera cylindrica*	-	-	-	-
10	*Kandelia candel*	-	3	14	2
11	*Excoecaria agallocha*	6	13	26	8
12	*Ceriops tagal*	124	-	-	-
13	*Aegiceras corniculatum*	-	1	-	-
14	*Acanthus ilicifolius*	-	25	26	20
15	*Derris heterophylla*	2	11	26	14
16	*Acrostichum aureum*	-	-	19	26

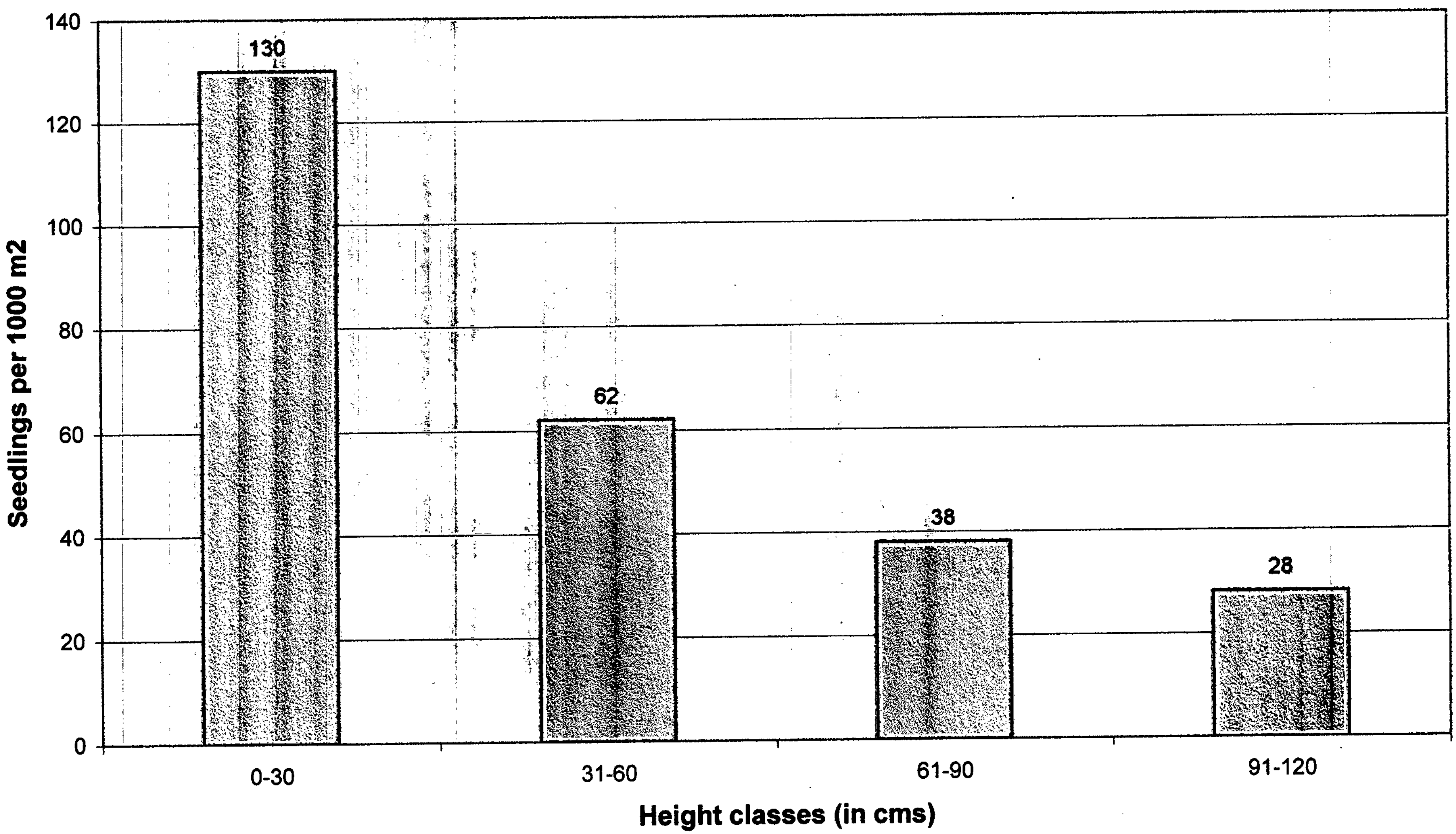
Index : - = Absent

TABLE-2.7 NATURAL REGENERATION OF MANGROVES ALONG TEREKHOL ESTUARY OF GOA

		Number of Plants in different height classes																															
	Location--------->	Keri								Kiranpani								Naibaga								Near KRC Railway line							
	Zone ------------->	Waterfront				Landward				Waterfront				Landward				Waterfront				Landward				Waterfront				Landward			
	Plot No----------->	1				2				3				4				5				6				7				8			
	Height Classes---->	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S.No	Species																																
1	*Rhizophora mucronata*	5	3		1					9	5	3	4					15	10	7	3												
2	*Rhizophora apiculata*																																
3	*Avicennia officinalis*	9	10	4	3	6	1			15	5	8	3					23	10	3	6												
4	*Avicennia marina*	2																															
5	*Avicennia alba*																																
6	*Sonneratia alba*	4	2	1	1					3	5	6	3					1															
7	*Sonneratia caseolaris*																	1	1														
8	*Bruguiera gymnorrhiza*																																
9	*Bruguiera cylindrica*																																
10	*Kandelia candel*																	3	2		1												
11	*Excoecaria agallocha*					2	1							2	2	3	1					3		1	1						2		1
12	*Ceriops tagal*	9	6	6	3																												
13	*Aegiceras corniculatum*													1																			
14	*Acanthus ilicifolius*													5								3	2							4	2		
15	*Derris heterophylla*					1								2								1								3			
16	*Acrostichum aureum*																					4								10			
	Total	29	21	11	8	9	2			27	15	17	10	10	2	3	1	43	23	10	10	11	2	1	1					17	4		1

Index for Height Classes (in cms): A=0-30; B=31-60; C=61-90; D=91-120.
Blank space against a particular species indicates its absence in particular height class.

Figure- 2.2 Overall natural regeneration pattern of Mangroves along Terekhol Estuary



2.3.2. Chapora Estuary

The Chapora estuary is about 30 kms in length. Near the mouth region mangroves were not present due to strong currents in the area. Mangroves started appearing near Morgim and up to a stretch of around 3 kms i.e. up to Siolim, *Sonneratia alba, Avicennia officinalis and Excoecaria agallocha* were the main mangrove species, however, they occurred in the form of scattered patches. Between Siolim and Oxel, within a stretch of around 2 kms, mangroves were seen occurring on the small islands and adjoining abandoned paddy fields. Natural regeneration of *Avicennia officinalis* and *Sonneratia alba* was excellent in this area. Due to lopping most of the *Sonneratia alba* trees were stunted in growth. *Porterasia* grass was common on the islands, which helped in stabilisation of the substratum. Just before the Vagalim village *Avicennia marina* and *Sonneratia alba* were present. Both these species were not present further towards upstream side. From Vagalim village, Camurlim village was about 3 kms. In this zone, mangrove vegetation was very scattered. *Avicennia officinalis* and *Excoecaria agallocha* were mainly present in this patch. Just opposite to Vagalim village a good patch of mangrove was present. Chikli village is at a distance of about 3 kms from Camurlim village. In this zone good mangrove vegetation occurred on small islands within the estuary. *Avicennia officinalis*, *Excoecaria agallocha, Acanthus ilicifolius,* and *Kandelia candel* were present in this area. Degraded mangroves patches were there in this zone. Colvale bridge is about 3 kms from the Chikli villlage. In this zone *Avicennia officinalis, Excoecaria agallocha, Sonneratia caseolaris, Kandelia candel* were the main species. *Thespesia populnea* (a mangrove associate) was also common in this area. Tall grasses were present in this region. This area was full of planted seedlings of *Rhizophora mucronata.* Natural regeneration of *Sonneratia caseolaris* was very good in this area. Konkan Railway Corporation's bridge is about 5 kms from Colvale bridge. In this zone mangrove vegetation occurred in the form of small-scattered patches. *Sonneratia caseolaris, Kandelia candel, Acrostichum aureum, Excoecaria agallocha, Acanthus ilicifolius, Avicennia marina, Rhizophora mucronata* and *Cassia intia* were present in this area. Tall grasses were present along the estuary. Coconut and *Thespesia populnea* trees were very commonly seen along the bank.

Towards the upstream side from Konkan Railway Corporation's bridge, water salinity was very low. In this zone mangrove vegetation was very scanty. On the banks of the estuary coconut plantation and *Thespesia populnea* trees were very common. Mangrove vegetation consisted of *Acanthus ilicifolius, Excoecaria agallocha, Cassia intia, Acrostichum aureum* and few trees of *Kandelia candel* as well as *Sonneratia caseolaris.* Near the village illicit cutting of *S. caseolaris* trees was observed for making poles. Villagers use gelatine (explosive) for catching fish. Detailed data collected on the basis of sample survey in different salinity zones along the Chapora estuary is shown in Table-2.8.

Special Observations along Chapora Estuary.

(1) All along the Chapora estuary, mangrove vegetation occurred in the form of small and scattered patches. Except few good patches, mangroves along the Chapora estuary can be classified as degraded mangroves.

(2) Illegal felling of mangroves for fuelwood is common feature along this estuary. As there is no easy supply of L.P.G. and kerosene etc. in the nearby villages, the villagers depend on mangrove forest for supply of fuelwood.

(3) There are abandoned paddy fields beyond the bank of the estuary. Mangroves have come up naturally in these areas. These fields have been abandoned due to the fact that paddy cultivation is not economical due to high labour cost and some other factors. This type of area can be managed on scientific basis for growing mangroves and supplying fuelwood to villagers on sustained yield basis. Most of such areas are under private/ communidade ownership. Government can enact suitable legislation for proper management of such type of areas. If the owners do not manage the area properly, government may acquire the land for proper management through Forest Department.

Results of natural regeneration survey along Chapora estuary have been shown in the Table-2.9. At Siolim (Polyhaline Zone) *Avicennia officinalis* and *Sonneratia alba* showed good regeneration. Moderate regeneration was found in *Excoecaria agallocha.* However, *Rhizophora mucronata* and *Derris heterophylla* had poor growth.

At Camurlim (Mesohaline Zone) *Avicennia officinalis* and *Excoecaria agallocha* showed profuse renewal of crop. Comparatively good regeneration was found in *Derris heterophylla* while *Kandelia candel* and *Acanthus ilicifolius* showed moderate growth.

At Colvale (Oligohaline Zone) profuse regeneration was noticed in *Sonneratia caseolaris*, *Acanthus ilicifolius* and *Kandelia candel.* Moderate regeneration was seen in *Acrostichum aureum. Avicennia officinalis, Excoecaria agallocha* and *Derris heterophylla* were found regenerating poorly.

Near Konkan Railway Corporation Bridge (Limnatic Zone) renewal of crop was seen in *Rhizophora mucronata, Avicennia marina, Sonneratia caseolaris, Kandelia candel, Excoecaria agallocha, Acanthus ilicifolius* and *Acrostichum aureum.*

Figure-2.3 shows overall natural regeneration pattern of mangroves (all species taken together) along Chapora estuary. The study shows that with the increase in height of plants their number decreases.

TABLE-2.8

MANGROVES IN VARIOUS SALINITY ZONES ALONG CHAPORA ESTUARY

S.No	Species	Trees per ha. at **Siolim** Polyhaline zone	Trees per ha. at **Camurlim** Mesohaline zone	Trees per ha. near **Colvale** Oligohaline zone	Trees per ha. near **KRC bridge** Limnetic zone
1.	*Rhizophora mucronata*	10	-	3	5
2	*Rhizophora apiculata*	-	-	-	-
3	*Avicennia officinalis*	27	159	15	-
4	*Avicennia marina*	6	-	-	3
5	*Avicennia alba*	-	-	-	-
6	*Sonneratia alba*	210	-	-	-
7	*Sonneratia caseolaris*	-	-	149	41
8	*Bruguiera gymnorrhiza*	-	-	-	-
9	*Bruguiera cylindrica*	-	-	-	-
10	*Kandelia candel*	-	21	247	24
11	*Excoecaria agallocha*	26	120	6	8
12	*Ceriops tagal*	-	-	-	-
13	*Aegiceras corniculatum*	-	-	-	-
14	*Acanthus ilicifolius*	-	26	30	13
15	*Derris heterophylla*	9	28	12	-
16	*Acrostichum aureum*	-	-	10	26

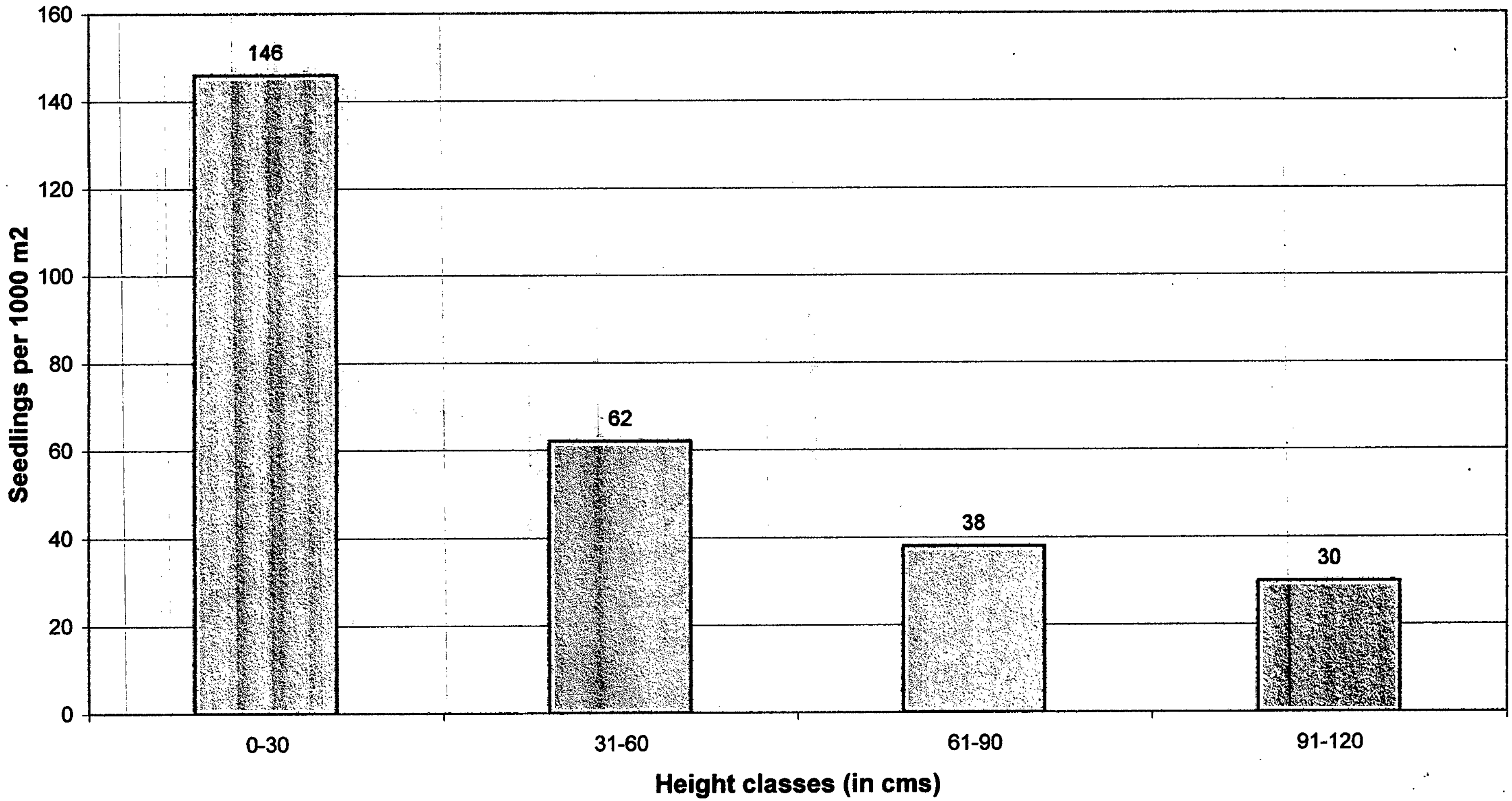
Index: - = Absent

TABLE-2.9 NATURAL REGENERATION OF MANGROVES ALONG CHAPORA ESTUARY OF GOA

		Number of Plants in different height classes																															
	Location--------->	Siolim								Camurlim								Colvale								Near KRC Bridge							
	Zone ------------>	Waterfront				Landward				Waterfront				Landward				Waterfront				Landward				Waterfront				Landward			
	Plot No---------->	1				2				3				4				5				6				7				8			
	Height Classes---->	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S.No	Species																																
1	*Rhizophora mucronata*	3		1																1						1	2						
2	*Rhizophora apiculata*																																
3	*Avicennia officinalis*	10	5	3	3					32	19	10	6					10	4														
4	*Avicennia marina*		2																								1						
5	*Avicennia alba*																																
6	*Sonneratia alba*	16	8	4	4																												
7	*Sonneratia caseolaris*																	10	6	5	5					5	1	1					
8	*Bruguiera gymnorrhiza*																																
9	*Bruguiera cylindrica*																																
10	*Kandelia candel*									4	4	3						15	4	3	6					3	1	1	1				
11	*Excoecaria agallocha*					5		3	4					10	10	7	5					3								1	2		
12	*Ceriops tagal*																																
13	*Aegiceras corniculatum*																																
14	*Acanthus ilicifolius*													5								6								3			
15	*Derris heterophylla*					3								6								3											
16	*Acrostichum aureum*																					4								5			
	Total	29	15	8	7	8		3	4	36	23	13	6	21	10	7	5	35	14	9	11	16				9	5	2	1	9	2		

Index for Height Classes (in cms): A=0-30; B=31-60; C=61-90; D=91-120.
Blank space against a particular species indicates its absence in particular height class

Figure-2.3 Overall natural regeneration pattern of Mangroves along Chapora Estuary



2.3.3. Mandovi Estuary

The Mandovi estuary is about 68 kms in length. It has several tributaries with total length of about 109 kms. Mouth region of this estuary from Miramar to Mandovi bridge at Panjim was devoid of mangrove vegetation due to strong wave action and pure sandy substratum which was not suitable for growth of mangroves. While moving from mouth region towards upstream region first big patch of mangroves was seen at Chorao Island. This area was storehouse of variety of mangrove species and excellent habitat for birds. Therefore, 178 ha area of this island was declared as Dr. Salim Ali Bird Sanctuary. First sample plot in Polyhaline zone was selected in this sanctuary. *Rhizophora mucronata, Sonneratia alba,* and *Avicennia officinalis* were the main species in this area. Just adjacent to the sanctuary on the landward side mangrove area has been reclaimed by the Goa's Fishery Department for development of prawn culture. From Panjim to Ribander, Forest Department raised mangrove plantations along the Mandovi estuary. Divar Island which is situated further upstream had luxuriant growth of mangroves. Second sample plot was selected in Mesohaline zone at Divar, which had *Rhizophora mucronata, R. apiculata, Kandelia candel, Sonneratia alba, Avicennia officinalis* and *Acanthus ilicifolius* as the main species of the area. Dhauji is situated further upstream in Oligohaline zone and the site for the third sample plot. Main mangrove species in this area were *Avicennia officinalis, Rhizophora mucronata, Excoecaria agallocha, Kandelia candel* and *Sonneratia alba*. Plate-2.1 shows *Kandelia candel* along Mandovi estuary. At Totem-Pilgao *Rhizophora mucronata, R. apiculata,* and *Excoecaria agallocha* were the main species. However, *Avicennia marina, Sonneratia alba, Kandelia candel* and

Excoecaria agallocha were also rarely seen. On further upstream side at Khandola, the salinity was low (Limnatic zone) and one sample plot was selected in this area. *Sonneratia caseolaris, Kandelia candel* and *Acrostichum aureum* were the main species in this area. Mapusa estuary is an important tributary of Mandovi estuary and had significant mangrove growth along its banks. Very old and huge trees of *Avicennia* were common at Betim, Britona and Aldona along the Mapusa estuary. All along from Betim to Pomburpa, and at Chorao successful mangrove plantations has been raised by the Forest Department. Plate-2.2 shows enchanting natural patch of *Avicennia* with *Rhizophora* plantation towards waterfront at Chorao. Data collected in various sample plots along Mandovi estuary is shown in Table-2.10.

Results of natural regeneration along Mandovi estuary have been presented in Table-2.11. At Chorao (Polyhaline Zone) good regeneration was seen in *Rhizophora mucronata, Avicennia officinalis, Sonneratia alba* and *Acanthus ilicifolius.* Poor renewal of crop was seen in *Rhizophora apiculata, Avicennia marina, A. alba, Bruguiera cylindrica, Kandelia candel, Excoecaria agallocha, Aegiceras corniculatum* and *Derris heterophylla.*

At Divar (Mesohaline Zone) good regeneration was seen in *Avicennia officinalis, Acanthus ilicifolius* and *Kandelia candel.* Moderate regeneration was seen in *Rhizophora apiculata, R. mucronata* and *Derris heterophylla.* Poor renewal of crop was seen in *Avicennia marina, Sonneratia alba, Bruguiera cylindrica,* and *Excoecaria agallocha.*

At Dhauji (Oligohaline Zone) good regeneration was noticed in *Avicennia officinalis*. Moderate regeneration was noticed in *Rhizophora mucronata* and *Excoecaria agallocha*. Poor renewal of crop was noticed in *Rhizophora apiculata, Sonneratia alba, S. caseolaris, Bruguiera gymnorrhiza, Kandelia candel* and *Acanthus ilicifolius*.

At Khandola (Limnatic Zone) good regeneration was seen in *Sonneratia caseolaris* and *Kandelia candel*. Poor regeneration was seen in *Rhizophora apiculata, R. mucronata, Avicennia officinalis, A. marina, Bruguiera gymnorrhiza, Excoecaria agallocha, Aegiceras corniculatum,* and *Derris heterophylla*.

Figure-2.4 shows overall natural regeneration pattern of mangroves (all species taken together) along Mandovi estuary. The study shows that with the increase in height of plants their number decreases.

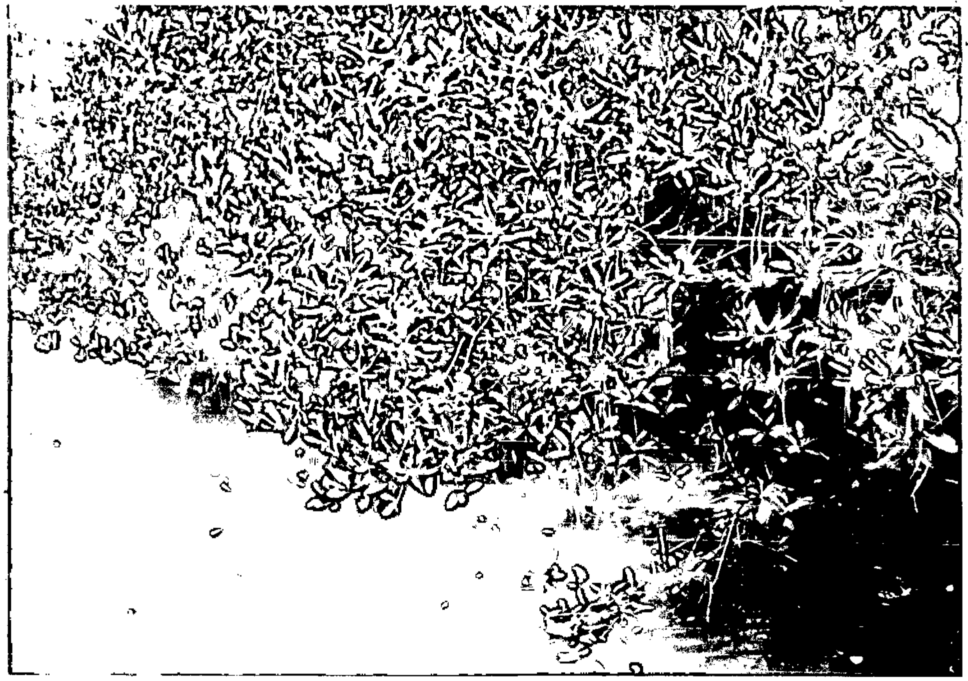


PLATE: 2.1

***Kandelia candel* along Mandovi estuary (Goa)**

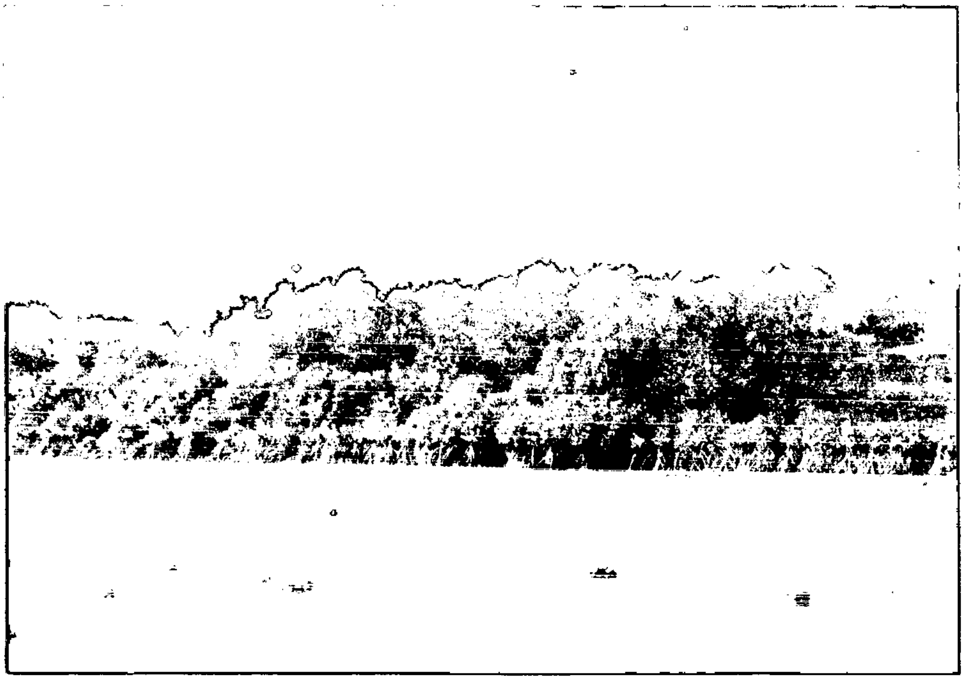


PLATE: 2.2

Enchanting natural patch of *Avicennia* with *Rhizophora* plantation towards waterfront at Chorao (Goa)

TABLE-2.10

MANGROVES IN VARIOUS SALINITY ZONES ALONG MANDOVI ESTUARY

S.No	Species	Trees per ha. at **Chorao** Polyhaline zone	Trees per ha. at **Divar** Mesohaline zone	Trees per ha. near **Dhauji** Oligohaline zone	Trees per ha. near **Khandola** Limnetic zone
1.	*Rhizophora mucronata*	63	50	42	4
2	*Rhizophora apiculata*	10	29	6	2
3	*Avicennia officinalis*	36	19	63	13
4	*Avicennia marina*	6	8	-	1
5	*Avicennia alba*	1	-	-	-
6	*Sonneratia alba*	54	21	15	-
7	*Sonneratia caseolaris*	-	-	1	56
8	*Bruguiera gymnorrhiza*	-	4	2	6
9	*Bruguiera cylindrica*	4	1	-	-
10	*Kandelia candel*	17	27	18	56
11	*Excoecaria agallocha*	4	6	30	4
12	*Ceriops tagal*	-	-	-	-
13	*Aegiceras corniculatum*	3	-	-	-
14	*Acanthus ilicifolius*	16	27	4	7
15	*Derris heterophylla*	28	8	-	-
16	*Acrostichum aureum*	-	-	-	69

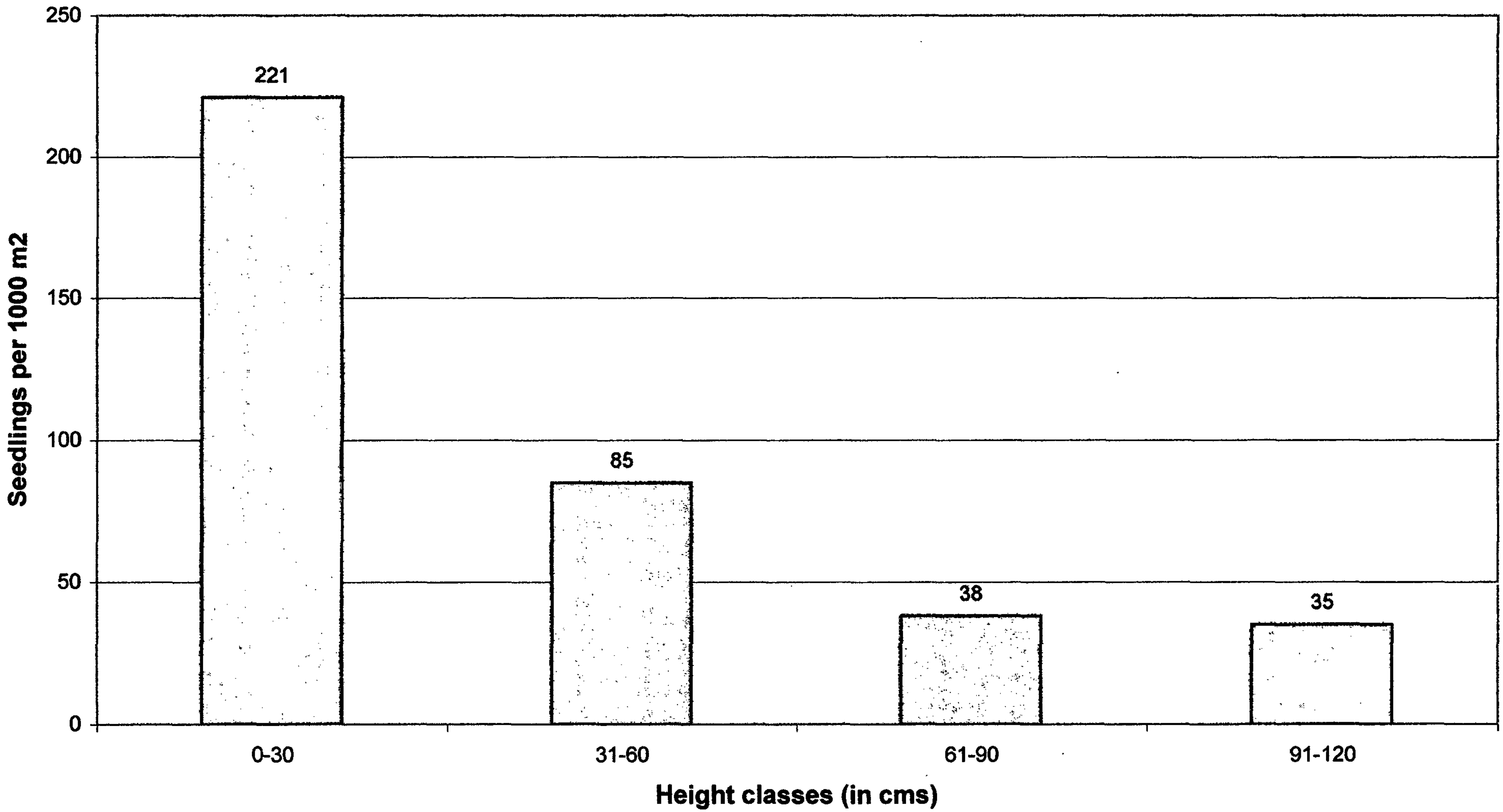
Index: - = Absent

TABLE– 2.11 NATURAL REGENERATION OF MANGROVES ALONG MANDOVI ESTUARY OF GOA

		Number of Plants in different height classes																															
	Location--------->	Chorao								Divar								Dhauji								Khandola							
	Zone ------------->	Waterfront				Landward				Waterfront				Landward				Waterfront				Landward				Waterfront				Landward			
	Plot No----------->	1				2				3				4				5				6				7				8			
	Height Classes---->	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S.No	Species																																
1	*Rhizophora mucronata*	9	7	3	4					10	6	3	1					8	5	2	2					1							
2	*Rhizophora apiculata*	6	3		1					6	3	3						5		1						2							
3	*Avicennia officinalis*	30	10	6	3					21	7	4	5					29	7	3	4					4							
4	*Avicennia marina*	5								2	1																1						
5	*Avicennia alba*	1																															
6	*Sonneratia alba*	9	7	3	3					6	3		1					3	3														
7	*Sonneratia caseolaris*																	1								11	10	4	5				
8	*Bruguiera gymnorrhiza*													2								1				3							
9	*Bruguiera cylindrica*					3									1																		
10	*Kandelia candel*	3	1							9	7	3	4					3	2	1						8	5	4	5				
11	*Excoecaria agallocha*					3	2							4	1							3	3	2	1					2			
12	*Ceriops tagal*																																
13	*Aegiceras corniculatum*					1																								1			
14	*Acanthus ilicifolius*					6								8								2											
15	*Derris heterophylla*					3								5																9			
16	*Acrostichum aureum*																																
	Total	63	28	12	11	16	2			54	27	13	11	19	2			49	17	7	6	6	3	2	1	29	16	8	10	12			

Index for Height Classes (in cms): A=0-30; B=31-60; C=61-90; D=91-120.
Blank space against a particular species indicates its absence in particular height class.

Figure-2.4 Overall natural regeneration pattern of Mangroves along Mandovi Estuary



2.3.4. Zuari Estuary

The Zuari estuary is 63 kms in length. Area wise maximum mangroves occur along this estuary. Mouth region was rocky and wave action was strong in this area. Because of these reasons mangroves were not found in the first 4-5 kms zone. First sample plot was selected in a Polyhaline zone at Durbhat. In this area *Avicennia marina* accounted for more than 50% of the total mangroves present. The important species in the area were *Sonneratia alba, Bruguiera gymnorrhiza* and *Rhizophora mucronata.* Other mangrove species, which were present in relatively smaller number, were *Avicennia officinalis, Excoecaria agallocha, Bruguiera cylindrica,* and *Aegiceras corniculatum.* Borim is situated in the upstream direction from Durbhat and falls within Mesohaline zone. Main species in this area were *Avicennia officinalis, Rhizophora mucronata* and *Sonneratia alba.* Occurrence wise lesser important mangroves in the area were *Excoecaria agallocha, Kandelia candel, Sonneratia caseolaris, Bruguiera gymnorrhiza,* and *Aegiceras corniculatum.* Shiroda is further upstream and located in Oligohaline zone. Third sample plot was selected in this area. *Avicennia officinalis, Kandelia candel, and Rhizophora apiculata* were the main mangrove species in this area. Other mangrove species present at Shiroda were *Sonneratia caseolaris, Excoecaria agallocha, Bruguiera gymnorrhiza* and *S.alba.* Panchwadi is situated further upstream side where water salinity was low. *Avicennia officinalis, Sonneratia caseolaris,* and *Kandelia candel* were the main species. Other mangrove species in this Limnatic zone were *Rhizophora mucronata, Excoecaria agallocha* and *Bruguiera gymnorrhiza.* Data collected from the sample plots along Zuari estuary has been presented in Table-2.12. As far as mangrove vegetation along Zuari estuary is concerned, following points are important: -

(a) *Rhizophora mucronata* and *Avicennia officinalis* were most abundant along Zuari estuary.

(b) *Rhizophora apiculata, Avicennia alba* and *Ceriops tagal* were not noticed.

(c) *Avicennia marina* was noticed in abundance at Durbhat (Polyhaline zone). It was not noticed anywhere else along the estuary.

(d) *Sonneratia alba* was thriving well in Mesohaline zone while *Sonneratia caseolaris* was thriving well in Limnatic zone.

(e) *Bruguiera gymnorrhiza* was locally dominant at some places in Mesohaline zone but very rare in Limnatic zone.

(f) *Bruguiera cylindrica* and *Aegiceras corniculatum* were extremely rare and on the verge of extinction along Zuari estuary.

Special observations along Zuari estuary

(i) Profuse natural regeneration of *Sonneratia caseolaris* was seen in the Panchwadi area. Nearby abandoned paddy fields had good growth of *Sonneratia caseolaris*. Trees of different age i.e. from very young seedlings to pole size crop were present. Area was full of tall grasses. Mature fruits come to the paddy field along with tidal water and get trapped in the area because of presence of grasses. As the fruit degenerates, seeds disperse and germinate in the area.

(ii) Illegal extraction of *Sonneratia caseolaris* poles was observed. Local villagers were collecting firewood and poles from Panchwadi area.

(iii) All along Zuari estuary natural regeneration of *Avicennia* species was profuse especially in adjoining abandoned paddy fields.

(iv) Along the bank of the estuary, natural regeneration of *Avicennia* was not uniform. It was confined to a strip of about five-meter width towards the land ward side as the seeds were deposited by wave action in this area.

(v) Wild rats were very common. Large population of wild rats was noticed in *Avicennia* dominated area at Borim.

(vi) Many old *Avicennia trees* had become hollow. Beehives were seen in hollow *Avicennia* trees.

Results of natural regeneration survey along Zuari estuary have been shown in Table-2.13. At Durbhat (Polyhaline Zone) good regeneration was noticed in *Avicennia marina, Sonneratia alba, Bruguiera gymnorrhiza,* and *Acanthus ilicifolius.* Moderate regeneration was noticed in *Rhizophora mucronata.* Poor renewal of crop was noticed in *Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha* and *Aegiceras corniculatum.*

At Borim (Mesohaline Zone), good natural regeneration was noticed in *Rhizophora mucronata, Avicennia officinalis, Sonneratia alba* and *Acanthus ilicifolius.* Poor renewal of crop was noticed in *Sonneratia caseolaris, Bruguiera gymnorrhiza, Kandelia candel, Excoecaria agallocha* and *Aegiceras corniculatum.*

At Shiroda (Oligohaline Zone) good renewal of crop was noticed in *Rhizophora mucronata, Avicennia officinalis, Kandelia candel, Acanthus ilicifolius* and *Derris heterophylla.* Poor regeneration was noticed in *Sonneratia alba, S. caseolaris, Bruguiera gymnorrhiza* and *Excoecaria agallocha.*

At Panchwadi (Limnatic Zone) good regeneration was noticed in respect of *Avicennia officinalis, Sonneratia caseolaris, Kandelia candel, Acanthus ilicifolius, Derris heterophylla* and *Acrostichum aureum.* Poor natural regeneration was noticed in *Bruguiera gymnorrhiza* and *Excoecaria agallocha.*

Figure-2.5 shows overall natural regeneration pattern of mangroves (all species taken together) along Zuari estuary. The study shows that with the increase in height of plants their number decreases.

TABLE-2.12

MANGROVES IN VARIOUS SALINITY ZONES ALONG ZUARI ESTUARY

S.N.	Species	Trees per ha. at **Durbhat** Polyhaline zone	Trees per ha. at **Borim** Mesohaline zone	Trees per ha. at **Shiroda** Oligohaline zone	Trees per ha. at **Panchwadi** Limnetic zone
1.	*Rhizophora mucronata*	78	147	80	8
2	*Rhizophora apiculata*	-	-	-	-
3	*Avicennia officinalis*	37	150	165	102
4	*Avicennia marina*	476	-	-	-
5	*Avicennia alba*	-	-	-	-
6	*Sonneratia alba*	128	52	6	-
7	*Sonneratia caseolaris*	-	11	9	66
8	*Bruguiera gymnorrhiza*	82	4	7	1
9	*Bruguiera cylindrica*	14	-	-	-
10	*Kandelia candel*	-	12	125	63
11	*Excoecaria agallocha*	17	26	9	8
12	*Ceriops tagal*	-	-	-	-
13	*Aegiceras corniculatum*	10	1	-	-
14	*Acanthus ilicifolius*	55	51	62	73
15	*Derris heterophylla*	-	-	61	51
16	*Acrostichum aureum*	-	-	-	26

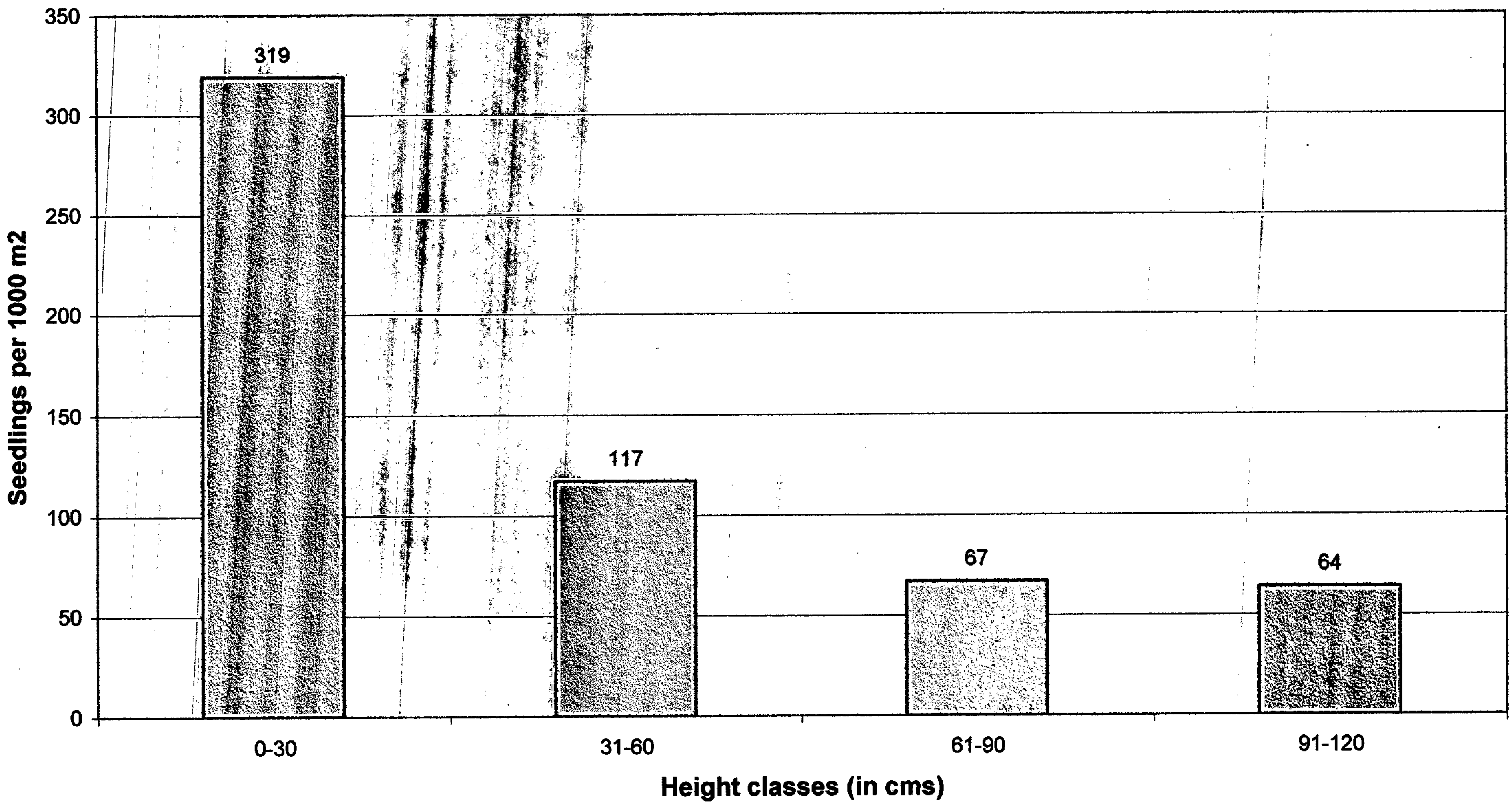
Index: - = Absent

TABLE– 2.13 NATURAL REGENERATION OF MANGROVES ALONG ZUARI ESTUARY OF GOA

		Number of Plants in different height classes																															
	Location--------->	Durbhat								Borim								Shiroda								Panchwadi							
	Zone ------------->	Waterfront				Landward				Waterfront				Landward				Waterfront				Landward				Waterfront				Landward			
	Plot No----------->	1				2				3				4				5				6				7				8			
	Height Classes---->	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S.No	Species																																
1	*Rhizophora mucronata*	8	8	2	1					16	9	4	6					11	10	7	8					2							
2	*Rhizophora apiculata*																																
3	*Avicennia officinalis*	13	5	1						48	11	9	6					55	16	7	8					16	10	5	5				
4	*Avicennia marina*	50	16	6	7																												
5	*Avicennia alba*																																
6	*Sonneratia alba*	11	5	3	7					7	3	4	4					3															
7	*Sonneratia caseolaris*									3		1							2							9	5	4	4				
8	*Bruguiera gymnorrhiza*					14	10	7	3					2	1							1		1						1	1		
9	*Bruguiera cylindrica*					4	1		1																								
10	*Kandelia candel*										2							14	6	3	6					6	6	5	3				
11	*Excoecaria agallocha*					3	1		1					3		3	2						2							2	1	1	
12	*Ceriops tagal*																																
13	*Aegiceras corniculatum*					3		1						1		1																	
14	*Acanthus ilicifolius*					7								10								9								7			
15	*Derris heterophylla*																					6								7			
16	*Acrostichum aureum*																													6			
	Total	82	34	12	15	31	12	8	5	74	25	18	16	16	1	4	2	83	34	17	22	16	2	1		33	21	14	12	23	2	1	

Index for Height Classes (in cms): A=0-30; B=31-60; C=61-90; D=91-120.
Blank space against a particular species indicates its absence in particular height class.

Figure-2.5 Overall natural regeneration pattern of Mangroves along Zuari Estuary



2.3.5. Cumbarjua Canal

The Cumbarjua canal joins Mandovi and Zuari estuaries and is about 15 kms in length. *Rhizophora mucronata, Avicennia officinalis, Acanthus ilicifolius and Derris heterophylla* were the main mangrove species along the canal. Mangrove vegetation was quite dense along the canal. Crocodiles were commonly observed in Cumbarjua canal of Goa. Table-2.14 gives various mangrove species in all the four sample plots laid down along the Cumbarjua canal.

Results of natural regeneration survey along Cumbarjua canal has been shown in Table-2.15. At Madkai (Polyhaline Zone), good renewal of crop was noticed in respect of *Rhizophora mucronata, Avicennia officinalis, Derris heterophylla* and *Acanthus ilicifolius.* Moderate regeneration was noticed in *Avicennia marina.* Poor regeneration was noticed in *Rhizophora apiculata*, *Bruguiera gymnorrhiza*, and *B. cylindrica.*

At Kundaim (Mesohaline Zone), good renewal of crop was noticed in *Avicennia officinalis, Bruguiera cylindrica, Excoecaria agallocha* and *Derris heterophylla.* Moderate regeneration was noticed in *Acrostichum aureum*. Poor crop renewal was noticed in *Rhizophora mucronata, R. apiculata*, *Avicennia marina, Sonneratia alba, S. caseolaris, Bruguiera gymnorrhiza* and *Acanthus ilicifolius.*

At Banastari (Oligohaline Zone), good regeneration was noticed in *Avicennia officinalis* and *Acanthus ilicifolius.* Moderate regeneration was noticed in

Rhizophora mucronata and *Derris heterophylla.* Poor renewal of crop was noticed in *Sonneratia caseolaris, Excoecaria agallocha* and *Acrostichum aureum.*

Near Jua St. Estevam (Limnatic Zone) moderate regeneration was noticed in *Rhizophora mucronata.* Poor renewal of crop was noticed in *Rhizophora apiculata, Avicennia officinalis, A. marina, Sonneratia alba, Bruguiera gymnorrhiza, Excoecaria agallocha, Acanthus ilicifolius* and *Acrostichum aureum.*

Figure-2.6 shows overall natural regeneration pattern of mangroves (all species taken together) along Cumbarjua canal. The study shows that with the increase in height of plants their number decreases except in height class 91-120 cms in which marginal increase in number of plants was noticed as compared to the height class 61-90 cms .

TABLE-2.14

MANGROVES IN VARIOUS SALINITY ZONES ALONG CUMBARJUA CANAL

S.No	Species	Trees per ha. at **Madkai**	Trees per ha. at **Kundaim**	Trees per ha. at **Banastari**	Trees per ha. near **Jua st. Estevam**
1.	*Rhizophora mucronata*	223	53	70	36
2	*Rhizophora apiculata*	4	2	-	4
3	*Avicennia officinalis*	162	108	109	21
4	*Avicennia marina*	32	17	-	4
5	*Avicennia alba*	-	-	-	-
6	*Sonneratia alba*	11	5	-	4
7	*Sonneratia caseolaris*	-	1	3	-
8	*Bruguiera gymnorrhiza*	2	5	-	1
9	*Bruguiera cylindrica*	1	100	-	-
10	*Kandelia candel*	-	-	17	-
11	*Excoecaria agallocha*	-	71	29	12
12	*Ceriops tagal*	-	-	-	-
13	*Aegiceras corniculatum*	-	-	-	-
14	*Acanthus ilicifolius*	50	16	62	10
15	*Derris heterophylla*	67	72	36	-
16	*Acrostichum aureum*	-	10	7	5

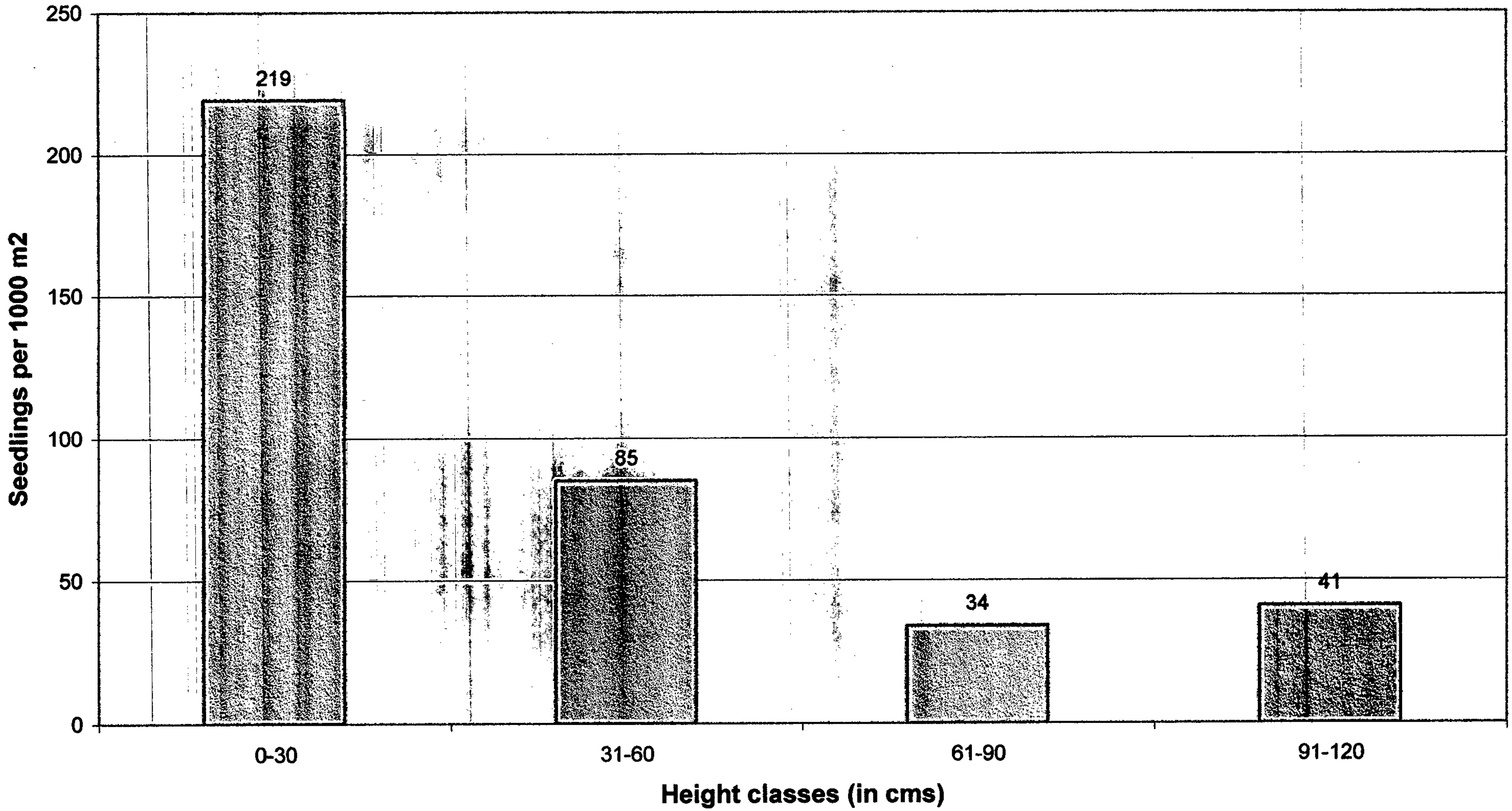
Index: - = Absent

TABLE– 2.15 NATURAL REGENERATION OF MANGROVES ALONG CUMBARJUA CANAL OF GOA

		Number of Plants in different height classes																															
	Location--------->	Madkai								Kundaim								Banastari								Near Jua St.Estevam							
	Zone ------------>	Waterfront				Landward				Waterfront				Landward				Waterfront				Landward				Waterfront				Landward			
	Plot No---------->	1				2				3				4				5				6				7				8			
	Height Classes--->	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S.No	Species																																
1	*Rhizophora mucronata*	16	10	5	7					6	3	1	1					7	7	1	4					10	3		3				
2	*Rhizophora apiculata*	3									1															3	1						
3	*Avicennia officinalis*	40	11	8	8					31	16	7	7					16	11	5	8					6	3						
4	*Avicennia marina*	15	6	3						10	5															1							
5	*Avicennia alba*																																
6	*Sonneratia alba*	3	2		1					1																1							
7	*Sonneratia caseolaris*										1							3	2														
8	*Bruguiera gymnorrhiza*					1	1							3																1			
9	*Bruguiera cylindrica*						1							10	6	5	3																
10	*Kandelia candel*																																
11	*Excoecaria agallocha*													6	3	3	3					3	1		1					3	1		
12	*Ceriops tagal*																																
13	*Aegiceras corniculatum*																																
14	*Acanthus ilicifolius*					7								3								7								2			
15	*Derris heterophylla*					8								6								5											
16	*Acrostichum aureum*													4								3								1			
	Total	77	29	16	16	16	2			48	26	8	8	32	9	8	6	26	20	6	12	18	1		1	21	7		3	7	1		

Index for Height Classes (in cms): A=0-30; B=31-60; C=61-90; D=91-120.
Blank space against a particular species indicates its absence in particular height class

Figure-2.6 Overall natural regeneration pattern of Mangroves along Cumbarjua Canal



2.3.6. Sal Estuary

The Sal is a small estuary having length of about 10 kms. All along the estuary mangroves were present in the form of scattered patches. At Betul (near mouth region) mangroves vegetation was scanty and there were few patches with good mangrove growth. At Coleavaddo good patches of mangroves along the estuary and on islands could be seen. Natural regeneration of *Avicennia officinalis* and *Sonneratia alba* was excellent on the islands. Local fishermen planted some *Rhizophora* seedlings in this area to check soil erosion along the bank of the estuary. Near the ferry point which was about 1 km. from Coleavaddo, *Avicennia officinalis* was most common. *Thespesia populnea* trees were abundant in the area. From this place up to Assolna bridge mangroves were very scanty and scattered but immediately after the Assolna bridge big patches of mangroves were present. Mangrove vegetation extended in the nearby paddy fields. About 70% of total mangrove area along Sal estuary fall between Assolna to just before Chinchinim village. Table-2.16 gives the number of various mangrove species in the four-sample plot laid along the Sal estuary.

Results of natural regeneration survey along Sal estuary have been shown in Table-2.17. At Betul (Polyhaline Zone) good renewal of crop was noticed in *Rhizophora mucronata, Avicennia officinalis* and *A. alba*. Poor renewal of crop was noticed in *Sonneratia alba*.

At Colcavaddo (Mesohaline Zone) good regeneration was noticed in *Avicennia officinalis*, *A. alba,* and *Derris heterophylla*. Moderate regeneration was noticed in *Rhizophora mucronata*. Poor renewal of crop was noticed in *Sonneratia alba, S. caseolaris*, *Bruguiera gymnorrhiza, Aegiceras corniculatum, Acanthus ilicifolius* and *Acrostichum aureum*.

At Assolna (Oligohaline Zone) good renewal of crop was noticed in *Avicennia officinalis* and moderate natural regeneration in *Aegiceras corniculatum*, *Acanthus ilicifolius, Derris heterophylla and Acrostichum aureum.* Poor regeneration was noticed in *Rhizophora mucronata*, *Sonneratia caseolaris* and *Excoecaria agallocha.*

At Chinchinim (Limnatic Zone) good regeneration was noticed in *Acanthus ilicifolius* and *Acrostichum aureum.* Moderate regeneration was noticed in *Excoecaria agallocha and Aegiceras corniculatum.* Poor renewal of forest crop was noticed *Rhizophora mucronata. Avicennia officinalis*, and *Derris heterophylla.*

Figure-2.7 shows overall natural regeneration pattern of mangroves (all species taken together) along Sal estuary. The study shows that with the increase in height of plants their number decreases.

TABLE-2.16

MANGROVES IN VARIOUS SALINITY ZONES ALONG SAL ESTUARY

S.N	Species	Trees per ha. at **Betul** Polyhaline zone	Trees per ha. at **Coleavaddo** Mesohaline zone	Trees per ha. near **Assolna** Oligohaline zone	Trees per ha. near **Chinchinim** Limnetic zone
1.	*Rhizophora mucronata*	116	116	18	5
2	*Rhizophora apiculata*	-	-	-	-
3	*Avicennia officinalis*	140	144	460	71
4	*Avicennia marina*	-	-	-	-
5	*Avicennia alba*	96	336	-	-
6	*Sonneratia alba*	2	19	-	-
7	*Sonneratia caseolaris*	-	1	2	-
8	*Bruguiera gymnorrhiza*	-	2	-	-
9	*Bruguiera cylindrica*	-	-	-	-
10	*Kandelia candel*	-	-	-	-
11	*Excoecaria agallocha*	-	-	18	22
12	*Ceriops tagal*	-	-	-	-
13	*Aegiceras corniculatum*	-	14	24	26
14	*Acanthus ilicifolius*	-	18	15	28
15	*Derris heterophylla*	-	29	31	9
16	*Acrostichum aureum*	-	5	11	27

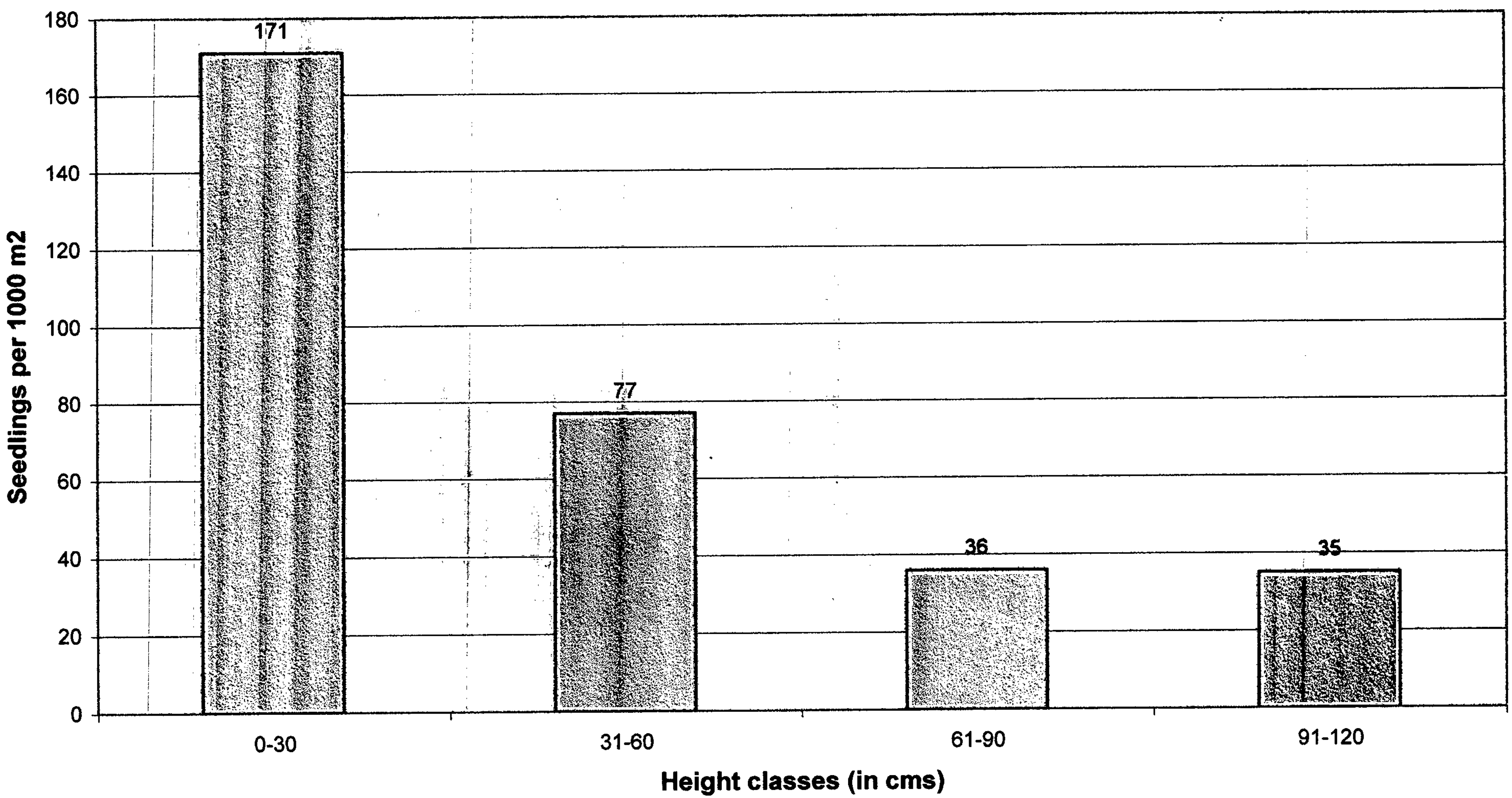
Index: - = Absent

TABLE– 2.17 NATURAL REGENERATION OF MANGROVES ALONG SAL ESTUARY OF GOA

		Number of Plants in different height classes (In Cms)																															
	Location---------->	Betul								Coleavaddo								Assolna								Chinchinim							
	Zone ------------->	Waterfront				Landward				Waterfront				Landward				Waterfront				Landward				Waterfront				Landward			
	Plot No----------->	1				2				3				4				5				6				7				8			
	Height Classes---->	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S.No	Species																																
1	*Rhizophora mucronata*	8	9	6	4					10	6	2	1					6		1	1					1							
2	*Rhizophora apiculata*																																
3	*Avicennia officinalis*	18	10	6	6					11	13	5	3					23	10	4	9					10	6	1	1				
4	*Avicennia marina*																																
5	*Avicennia alba*	7	5	3	3					33	16	7	7																				
6	*Sonneratia alba*	2								4	2																						
7	*Sonneratia caseolaris*										1							2															
8	*Bruguiera gymnorrhiza*									1				1																			
9	*Bruguiera cylindrica*																																
10	*Kandelia candel*																																
11	*Excoecaria agallocha*																					2	1		1					4	2	3	
12	*Ceriops tagal*																																
13	*Aegiceras corniculatum*													3	1		1					6	2	2						2	2		2
14	*Acanthus ilicifolius*													3								4								6			
15	*Derris heterophylla*													6								5								2			
16	*Acrostichum aureum*													2								4								6			
	Total	35	24	15	13					59	38	14	11	15	1		1	31	10	5	10	21	3	2	1	11	6	1	1	20	4	3	2

Index for Height Classes (in cms): A=0-30; B=31-60; C=61-90; D=91-120.
Blank space against a particular species indicates its absence in particular height class.

Figure-2.7 Overall natural regeneration pattern of Mangroves along Sal Estuary



2.3.7. Talpona Estuary

The Talpona is a small estuary approximately 9 kms. in length. From the mouth towards upstream side up to a distance of about 3 kms. mangrove vegetation was very scanty and scattered. Most of the mangroves along Talpona estuary were there between Mutal village and Sadolshem village. Mangrove vegetation was also seen in abandoned paddy fields adjoining estuarine bank. In the Mutal village just before the Konkan Railway Corporation (KRC) bridge luxuriant growth of mangroves was seen. In this area very tall *Rhizophora mucronata* trees (up to 20-meter height) were noticed. Height of *Bruguiera gymnorrhiza* trees extend up to 12 meters. Such tall trees of these species were not observed anywhere else in Goa. Other mangrove species in this area are *Avicennia officinalis, Derris heterophylla, Excoecaria agallocha, Sonneratia alba,* and *Acanthus ilicifolius. Thespesia populnea* (a mangrove associate) was very commonly found in this area. In and around Sadolshem village, areas under mangrove vegetation were seen. Mangroves were also growing in the adjoining private land where tidal water entered during high tide time. Main mangrove species in this area were *Avicennia officinalis, Acanthus ilicifolius, Excoecaria agallocha* and *Sonneratia alba.* After Sadolshem village mangrove vegetation was very rare as we moved further upstream side. Table-2.18 gives the data on number of mangrove plants present in various sample plots laid along the Talpona estuary.

Results of natural regeneration survey have been shown in Table-2.19. At Talpona (Polyhaline Zone) good renewal of crop was noticed in *Sonneratia alba.*

Moderate regeneration was noticed in *Avicennia officinalis* and *Excoecaria agallocha*. Poor renewal of crop was noticed in *Rhizophora mucronata, Avicennia marina, Acanthus ilicifolius* and *Derris heterophylla.*

Near Talpona -Mutal Road (Mesohaline Zone) good regeneration was noticed in *Aegiceras corniculatum*. Moderate renewal of crop was noticed in *Avicennia officinalis, A. marina, Sonneratia alba, Excoecaria agallocha* and *Acrostichum aureum.* Poor regeneration was noticed in *Bruguiera gymnorrhiza* and *Acanthus ilicifolius.*

Near Mutal village (Oligohaline Zone) good renewal of crop was noticed in *Avicennia officinalis, Bruguiera gymnorrhiza, Excoecaria agallocha*, and *Acanthus ilicifolius.* Moderate regeneration was noticed in *Rhizophora mucronata, Sonneratia alba, Derris heterophylla* and *Acrostichum aureum.* Poor natural regeneration was noticed in *Aegiceras corniculatum.*

Near Sadolshem (Limnatic Zone) good renewal of crop was noticed in *Avicennia officinalis.* Moderate regeneration was noticed in *Excoecaria agallocha, Acanthus ilicifolius, Derris heterophylla* and *Acrostichum aureum.* Poor regeneration was noticed in *Sonneratia alba.*

Figure-2.8 shows overall natural regeneration pattern of mangroves (all species taken together) along Talpona estuary. The study shows that with the increase in height of plants their number decreases.

TABLE-2.18

MANGROVES IN VARIOUS SALINITY ZONES ALONG TALPONA ESTUARY

S.No	Species	Trees per ha. at **Talpona** Polyhaline zone	Trees per ha. at **Talpona-Mutal road** Mesohaline zone	Trees per ha. at **Mutal village** Oligohaline zone	Trees per ha. at **Sadolshem** Limnetic zone
1.	*Rhizophora mucronata*	15	-	77	-
2	*Rhizophora apiculata*	-	-	-	-
3	*Avicennia officinalis*	10	42	119	102
4	*Avicennia marina*	4	23	-	-
5	*Avicennia alba*	-	-	-	-
6	*Sonneratia alba*	291	82	41	9
7	*Sonneratia caseolaris*	-	-	-	-
8	*Bruguiera gymnorrhiza*	-	23	82	-
9	*Bruguiera cylindrica*	-	-	-	-
10	*Kandelia candel*	-	-	-	-
11	*Excoecaria agallocha*	27	50	199	49
12	*Ceriops tagal*	-	-	-	-
13	*Aegiceras corniculatum*	-	260	27	-
14	*Acanthus ilicifolius*	5	11	29	15
15	*Derris heterophylla*	13	-	26	17
16	*Acrostichum aureum*	-	20	10	19

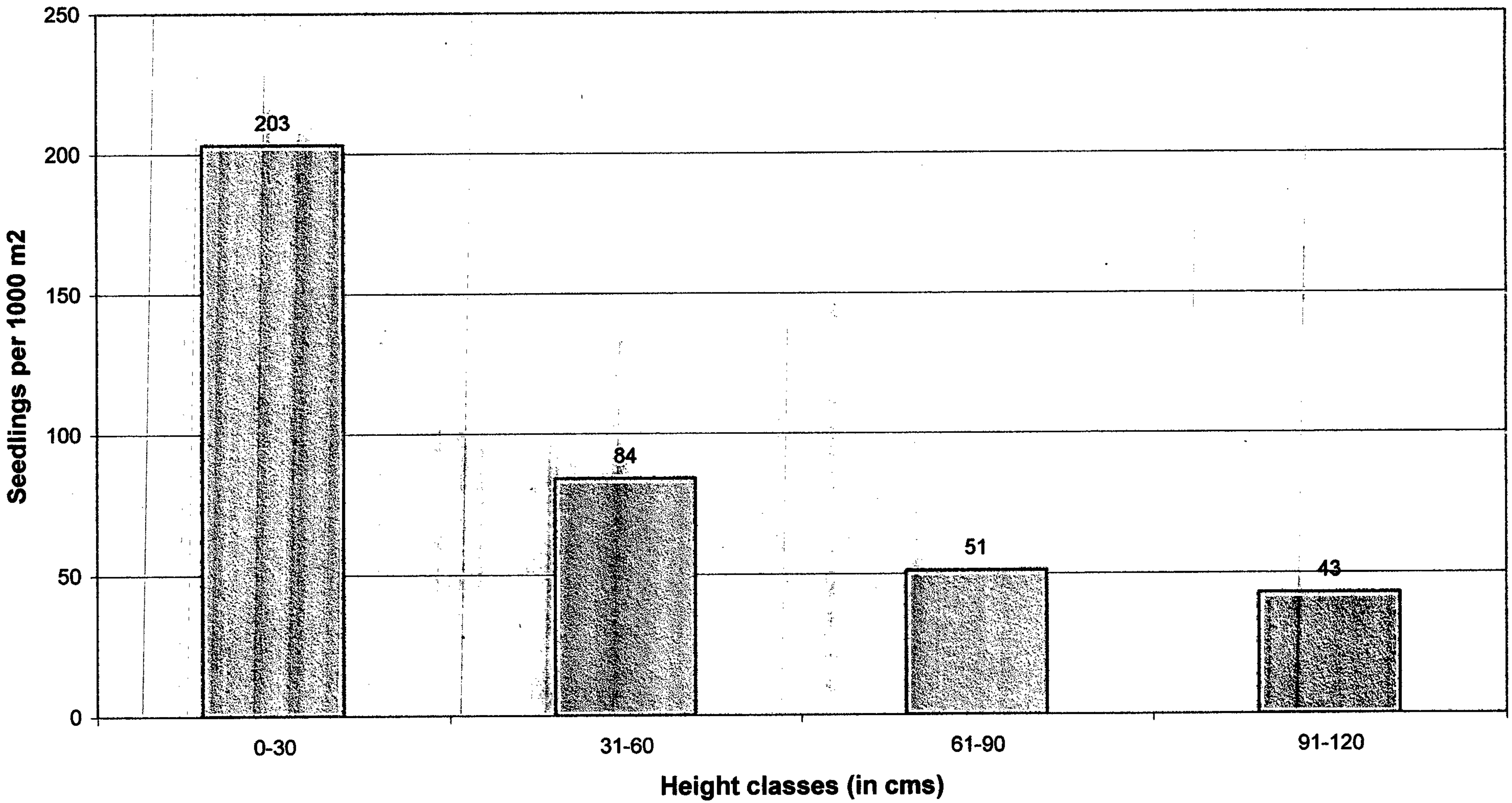
Index : - = Absent

TABLE– 2.19 NATURAL REGENERATION OF MANGROVES ALONG TALPONA ESTUARY OF GOA

		Number of Plants in different height classes																															
	Location--------->	Talpona								Talpona-Mutal Road								Mutal village								Sadolshem							
	Zone ------------>	Waterfront				Landward				Waterfront				Landward				Waterfront				Landward				Waterfront				Landward			
	Plot No---------->	1				2				3				4				5				6				7				8			
	Height Classes--->	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S.No	Species																																
1	*Rhizophora mucronata*	3	4															8	2	3	1												
2	*Rhizophora apiculata*																																
3	*Avicennia officinalis*	10	3	3	1					16	6	3	1					34	16	8	5					19	10	6	4				
4	*Avicennia marina*	2								9	2	2	2																				
5	*Avicennia alba*																																
6	*Sonneratia alba*	16	9	6	6					6	3	1	4					6	6	3	1					3	1		1				
7	*Sonneratia caseolaris*																																
8	*Bruguiera gymnorrhiza*													5	1	2	1					5	5	4	5								
9	*Bruguiera cylindrica*																																
10	*Kandelia candel*																																
11	*Excoecaria agallocha*					4	1	2	2					5	2	3	3					10	6	5	4					6	6	1	2
12	*Ceriops tagal*																																
13	*Aegiceras corniculatum*													19	10	4	4					3	1	1	1								
14	*Acanthus ilicifolius*					1								2								6								4			
15	*Derris heterophylla*					2																5								5			
16	*Acrostichum aureum*													4								4								5			
	Total	31	16	9	7	7	1	2	2	31	11	6	7	35	13	9	8	48	24	14	7	33	12	10	10	22	11	6	5	20	6	1	2

Index for Height Classes (in cms): A=0-30; B=31-60; C=61-90; D=91-120.
Blank space against a particular species indicates its absence in particular height class.

Figure-2.8 Overall natural regeneration pattern of Mangroves along Talpona Estuary



2.3.8. Galgibag Estuary

The Galgibag estuary is about 16 kms in length with dense mangrove vegetation. Near Galgibag, which is close to the estuary mouth, mangrove vegetation was very dense. At Galgibag lot of *Rhizophora apiculata, R. mucronata, Avicennia officinalis* and *Sonneratia alba* trees were noticed. Other mangrove species, which were present in lesser number at Galgibag, included *Avicennia marina* and *Derris heterophylla.* Carai maxim village is about 5 kms. from Poinguinim on the Poinguinim -Karwar road. Huge *Avicennia officinalis* trees could be seen in this locality. Huge heaps of mud made by the mud lobsters were seen in this area. Except *Avicennia marina* all other mangroves species present at Galgibag were also present in this area. At Carai-maxim *Avicennia officinalis* and *Excoecaria agallocha* were the main mangrove species. In the up stream direction from Carai-maxim water salinity was low but good mangrove patches consisting of *Rhizophora mucronata*, *Avicennia officinalis* and *Excoecaria agallocha* as main species were present. Table-2.20 gives the data on mangroves in various salinity zones along Galgibag estuary.

Results of natural regeneration survey along Galgibag estuary have been shown in Table-2.21. Near Galgibag (Polyhaline Zone) good renewal of crop was noticed in *Rhizophora mucronata, R. apiculata* and *Sonneratia alba.* Moderate regeneration was noticed in *Avicennia officinalis* and *Derris heterophylla* and *Acrostichum aureum.* Poor regeneration was noticed in *Avicennia marina.*

Between Galgibag-Carai maxim (Mesohaline Zone) good regeneration was noticed in *Rhizophora apiculata, Avicennia officinalis* and *Sonneratia alba.* Moderate renewal of forest crop was noticed in *Rhizophora mucronata.* Poor regeneration was noticed in *Derris heterophylla.*

Near Carai maxim (Oligohaline Zone) good renewal of crop was noticed in *Avicennia officinalis* and *Excoecaria agallocha.* Moderate regeneration was noticed in *Avicennia marina* and *Acanthus ilicifolius.* Poor regeneration was noticed in *Derris heterophylla.*

In a sample plot located about 3 kms. upstream side from Carai maxim in Limnatic Zone, good regeneration was noticed in *Rhizophora mucronata, Avicennia officinalis* and *Excoecaria agallocha.* Moderate regeneration was noticed in *Acanthus ilicifolius.* Poor renewal of crop was noticed in *Bruguiera gymnorrhiza, Derris heterophylla* and *Acrostichum aureum.*

Figure-2.9 shows overall natural regeneration pattern of mangroves (all species taken together) along Galgibag estuary. The study shows that with the increase in height of plants their number decreases.

TABLE-2.20

MANGROVES IN VARIOUS SALINITY ZONES ALONG GALGIBAG ESTUARY

S.N.	Species	Trees per ha. at **Galgibag** Polyhaline zone	Trees per ha. between **Galgibag** and **Carai-Maxem** Mesohaline zone	Trees per ha. at **Carai-Maxim** Oligohaline zone	Trees per ha. at 3Kms. from **Carai-Maxim** Limnetic zone
1	*Rhizophora mucronata*	126	67	-	168
2	*Rhizophora apiculata*	260	92	-	-
3	*Avicennia officinalis*	231	118	201	152
4	*Avicennia marina*	7	-	30	-
5	*Avicennia alba*	-	-	-	-
6	*Sonneratia alba*	210	87	-	-
7	*Sonneratia caseolaris*	-	-	-	-
8	*Bruguiera gymnorrhiza*	-	-	-	16
9	*Bruguiera cylindrica*	-	-	-	-
10	*Kandelia candel*	-	-	-	-
11	*Excoecaria agallocha*	-	-	192	112
12	*Ceriops tagal*	-	-	-	-
13	*Aegiceras corniculatum*	-	-	-	-
14	*Acanthus ilicifolius*	-	-	20	18
15	*Derris heterophylla*	28	7	18	7
16	*Acrostichum aureum*	-	-	-	17

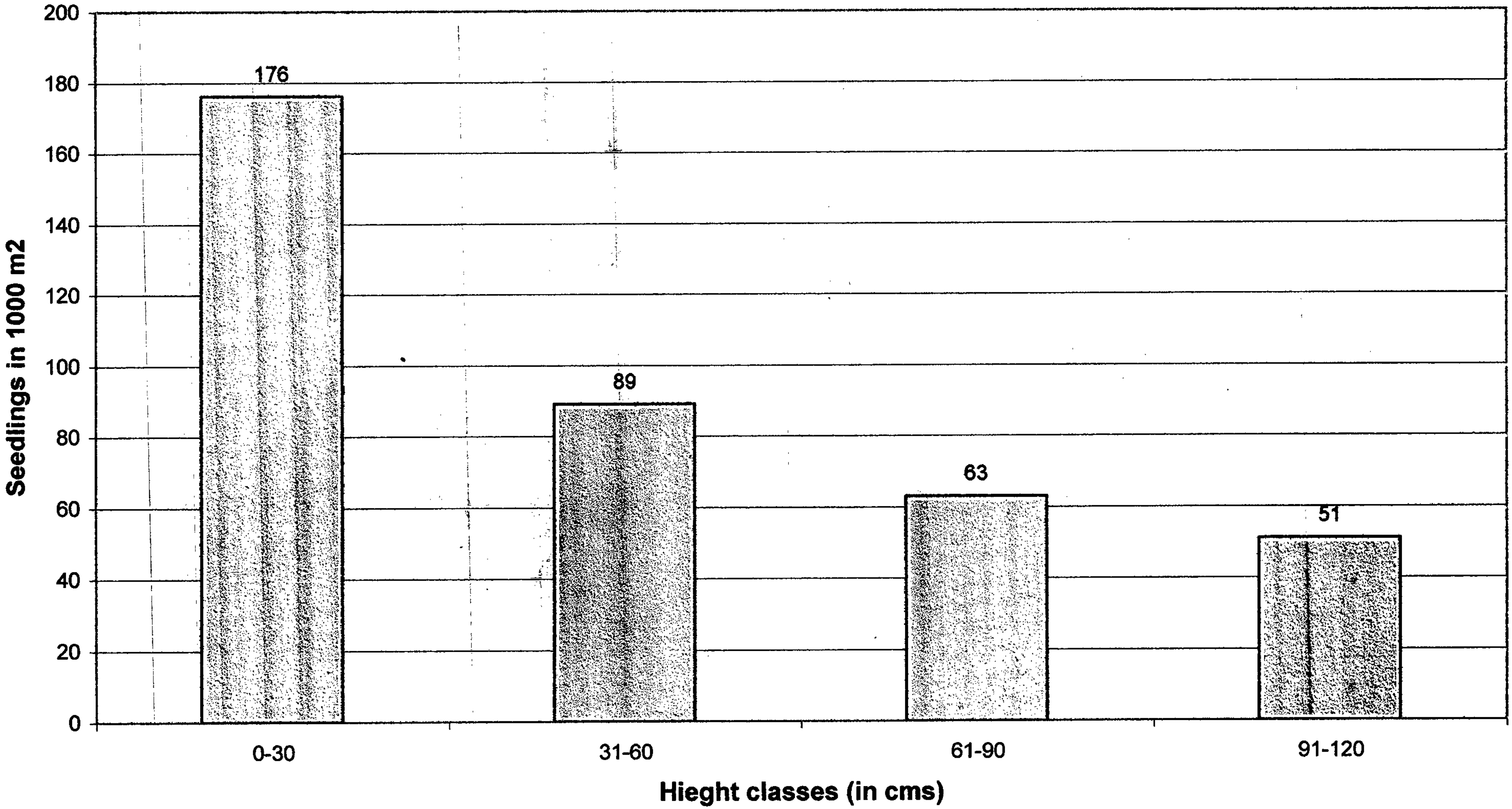
Index: - = Absent

TABLE- 2.21 NATURAL REGENERATION OF MANGROVES ALONG GALGIBAG ESTUARY OF GOA

		Number of Plants in different height classes																															
	Location---------->	Galgibag								Between Galgibag-Carai maxim								Carai maxim								3 Kms upstream side from Carai maxim							
	Zone ------------->	Waterfront				Landward				Waterfront				Landward				Waterfront				Landward				Waterfront				Landward			
	Plot No----------->	1				2				3				4				5				6				7				8			
	Height Classes---->	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S.No	Species																																
1	*Rhizophora mucronata*	10	8	7	3					6	3	2	2													8	8	6	4				
2	*Rhizophora apiculata*	11	10	6	7					8	5	6	5																				
3	*Avicennia officinalis*	20	9	6	2					16	10	6	4					25	11	9	5					16	11	6	4				
4	*Avicennia marina*	4		1														4	2		2												
5	*Avicennia alba*																																
6	*Sonneratia alba*	9	4	3	4					6	3	3	4																				
7	*Sonneratia caseolaris*																																
8	*Bruguiera gymnorrhiza*																													6	4		
9	*Bruguiera cylindrica*																																
10	*Kandelia candel*																																
11	*Excoecaria agallocha*																					10	6	3	6					16	6	7	5
12	*Ceriops tagal*																																
13	*Aegiceras corniculatum*																																
14	*Acanthus ilicifolius*																					4								4			
15	*Derris heterophylla*					5								1								3								2			
16	*Acrostichum aureum*																													3			
	Total	54	31	23	16	5				36	21	17	15	1				29	13	9	7	17	6	3	6	24	19	12	8	31	10	7	5

Index for Height Classes (in cms): A=0-30; B=31-60; C=61-90; D=91-120.
Blank space against a particular species indicates its absence in particular height class.

Figure-2.9 Overall natural regeneration pattern of Mangroves along Galgibag Estuary



2.4. DISCUSSION

The flora and ecology of the mangroves along the Goa Coast were studied by Anthony *et al.*, (1974), Gomes and Mavin Kurvi (1982), Jagtap (1985a, 1985b & 1986), Jagtap and Untawale (1980, 1981 & 1986), Matondkar *et al.*, (1980a & 1980b), Murti and Das (1972), Nayar (1980), Oertel (1988), Parulekar *et al.*, (1980, 1984), Querisi (1957), Untawale *et al.*, (1976, 1977, 1981 & 1982), Wagle (1982). As far as natural regeneration survey of mangrove species is concerned, detailed information on the past status of natural regeneration is not available. Probably, detailed work on the topic was not carried out earlier.

Distribution of mangroves in Goa was observed to be mainly influenced by salinity. It was suggested by Clarke and Hannon (1967) that the distribution of mangroves appeared to be closely related to topography and tidal amplitude, which in turn determined the degree and pattern of tidal inundation. The mangroves of Goa generally got inundated by an average tidal amplitude of 1.3 m. There was marked fluctuation in the number of tides above and below the average per month, which for Goa, seemed to be in the range of 52-78, which helped in inundation of mangroves very frequently. Along the estuaries of Goa at many localities topography seemed to be favourable for mangroves establishment and growth. However, the distribution of mangroves has been checked by construction of bunds for agricultural purposes or fish farming. The bund construction around mangroves enhances siltation, which deteriorated the nutrient status of soil and adversely affected the mangrove growth. Also, the bunds restricted the movement of mangrove seedlings and thereby prevented new establishment of mangroves (Jagtap, 1985).

The mangroves along the coastal zones of Goa and the estuaries mouths are relatively poor and degraded for the anthropogenic causes (Naskar & Mandal, 1999). The mangrove areas in the different estuaries of Goa were estimate only 20 sq kms (Untawale, 1982). Sidhu (1963a) reported the total coastal mangrove zones of Maharashtra, Gujarat and Karnataka as 622 sq kms while Blasco (1975 & 1977) reported only 200 sq kms mangroves on the coastlines of the three maritime states. But the Govt Of India Publication (Anonymous, 1985) reported mangrove area of Goa as 200 sq kms which is wrongly represented instead of 20 sq kms. The Satellite Imagery report from the Space Application Centre (Anonymous, 1992) reported the combined mangrove area of Maharashtra and Goa as 148.4 sq kms.

Naskar & Mandal (1999) have reported 17 mangrove species from Goa while Govt of India Report (Anonymous, 1987) and Jagtap *et al.*, (1995) reported 20 mangroves along the Mandovi and Zuari estuaries, though in very degraded manner. Along the Goa coast, mangrove distribution is of fringing type, in general. (Untawale and Parulekar, 1976).

Untawale *et al.*, (1982) studied detailed distribution in mangroves of Goa and reported 15 species of mangroves belonging to 10 genera. The reported dominant species were *Rhizophora mucronata, Sonneratia alba* and *Avicennia officinalis.* Other co-dominant species were *Rhizophora apiculata, Sonneratia caseolaris,* *Kandelia candel, Bruguiera gymnorrhiza, B. parviflora, Aegiceras corniculatum, Excoecaria agallocha, Acanthus ilicifolius* and *Derris heterophylla*. The other reported associated species were *Thespesia populnia, Clerodendron inerme, Halophila biccarii* and *Acrostichum aureum. Rhizophora mucronata, Sonneratia alba* and *Avicennia* species were reported to be dominant in the polyhaline region while *Bruguiera parviflora, B. gymnorrhiza, Acanthus illicifolius, Avicennia* were common in mesohaline zone. In the region of low salinity (0.5-5 ppt), *Kandelia candel, Sonneratia caseolaris* were the only mangroves seen with their associates *Acrostichum aureum* and *Cyperus* species. Mangroves occur all along the seven estuaries and Cumbarjua canal in Goa. Zuari estuary is different from other estuaries as it a negative estuary with more fresh water influence. Salinity is very low towards upstream region as most of the glycophytes were reported to be growing along the banks after Savordem (Untawale *et al.*, 1973).

About 90% mangroves existed along Mandovi and Zuari estuaries and remaining 10% along the 5 estuaries of Goa. The estuaries like Terekhol, Chapora, Sal and Talpona were observed to be unimportant from the forestry point of view, as mangrove vegetation was very poor. The dwarf and thin mangrove vegetation along the estuaries was due to constant indiscriminate cutting and grazing (Jagtap, 1985).

The mangrove formation along Goa coast is of fringing nature and shows different ranges of distribution. *Acanthus ilicifolius, Sonneratia alba, Rhizophora mucronata, Avicennia officinalis, Excoecaria agallocha* showed maximum range of distribution, while *Kandelia rheedi, Sonneratia caseolaris, Acrostichum* *aureum* had medium range of distribution. Species like *Rhizophora apiculata, Bruguiera gymnorrhiza, B. Parviflora, Ceriops tagal, Avicennia marina* and *Aegiceras corniculatum* were observed to be in the minimum range of distribution (Jagtap, 1985).

The dominant mangrove flora of Goa are *Avicennia officinalis, A. alba, Rhizophora mucronata, Excoecaria agallocha, Sonneratia alba, S. caseolaris, Kandelia candel, Bruguiera gymnorrhiza, B. cylindrica, Derris heterophylla.* Here the less dominant mangrove are *Rhizophora apiculata, Aegiceras corniculatum, Avicennia marina, Ceriops tagal* (Naskar & Mandal, 1999).

For the purpose of present study, occurrence of mangroves along different estuaries in Goa was classified into four categories viz. Absent, Rare, Common and Dominant. Relative abundance of mangrove species along estuaries of Goa has been shown in Table-2.22.

Rhizophora mucronata was dominant along all the estuaries with the exception of Chapora estuary where it was rare. The species was showing good natural regeneration along all the estuaries except Talpona and Chapora estuaries where it is moderate and poor respectively. Jagtap (1985) reported *Rhizophora mucronata* as dominant along Mandovi and Zuari estuaries. Poor natural regeneration of the species along Chapora estuary seems to be main cause of its rare occurrence. Walsh (1967) observed that many species belonging to the family *Rhizophoraceae* grow better in the Polyhaline region.

Rhizophora apiculata was dominant along Galgibag estuary, common along Mandovi estuary and rare along Cumbarjua canal. Along all other estuaries it was absent. Thus, we see that in contrast to *Rhizophora mucronata, R. apiculata* had very limited geographical distribution. *R. apiculata* was showing good, moderate and poor natural regeneration along Galgibag, Mandovi estuaries and Cumbarjua Canal respectively. Although Untawale *et al.,* (1982) reported absence of *Rhizophora apiculata* along Galgibag estuary but during the course of present study this species was found growing dominantly.

Avicennia officinalis was dominant and showing Good natural regeneration along all the estuaries in Goa. A single tree of the species produces thousands of seeds every year. The seeds are deposited along the banks of the estuaries by the action of waves and wind and also enter in the adjoining land along with water during the high tide. Most of these seeds do not go back with the low tide as they get entangled in the pre-existing vegetation in the area and profusely germinate there. This mode of natural regeneration was also observed in other species of *Avicennia* and in *Sonneratia alba* and *S. caseolaris.* Such profuse natural regeneration of *Avicennia* could be seen near Panjim itself at Chorao and vacant fields along Panjim- Margao road. Dagar and Singh (1999) repoted absence of *Avicennia officinalis* from Goa which was found incorrect.

Avicennia marina was dominant along Zuari estuary and was showing Good natural regeneration. The species was common along Cumbarjua canal and Galgibag estuary and absent along Sal estuary. Along all other estuaries it was rarely found. Untawale *et al.*, (1982) reported this species as rare along Mandovi, Zuari estuaries, Cumbarjua canal and absent along all other remaining estuaries.

Avicennia alba was dominant along Sal estuary and rare along Mandovi estuary where it was showing Good and Poor natural regeneration respectively. Along all other estuaries the species is absent. Naskar & Mandal (1999) reported *Avicennia. alba* as one of the dominant mangroves in Goa which does not seem to be appropriate when we compare it with the results of present study on overall distribution of this particular species in Goa.

Sonneratia alba was dominant and showing Good natural regeneration along all the estuaries except Cumbarjua canal and Sal estuary where it was rare in occurrence and showing Poor natural regeneration. Jagtap (1985) reported this species as dominant along Mandovi and Zuari estuaries.

Sonneratia caseolaris was dominant along Chapora, Mandovi and Zuari estuaries and showing Good renewal of the crop. The species was rare along Terekhol, Cumbarjua canal and Sal estuary and showing Poor regeneration. The species was absent along Talpona and Galgibag estuaries. Status Report on mangroves, published by the Government of India (Anonymous, 1987) reported *Sonneratia caseolaris* only from the Goa; though Naskar & Mandal (1999) reported *Sonneratia caseolaris* from Chhota Sudhanyakhali canal side of the Sunderbans (West Bengal). *Sonneratia caseolaris,* which has a very limited distribution along the Indian coast, was noticed abundantly in low salinity areas of various estuaries during the course of present study.

Bruguiera gymnorrhiza was dominant along Zuari and Talpona estuaries where it was showing Good and Poor regeneration respectively. The species was rare along Mandovi, Cumbarjua canal, and Sal and Galgibag estuaries. The species was absent along Terekhol and Chapora estuaries. Untawale *et al.,* (1982) reported this species common along Mandovi estuary, Cumbarjua canal; rare along Zuari and Sal estuaries and absent along the remaining estuaries.

Bruguiera cylindrica was locally dominant along Cumbarjua canal where it was showing Good renewal of the forest crop. It was confined mainly near Kundaim along Cumbarjua Canal. It was rarely found along Mandovi and Zuari estuaries. The species was not found along other estuaries. Dagar and Singh (1999) repoted absence of *Bruguiera cylindrica* and presence of *B. parviflora* from Goa. Probably, they misidentified the species *B. cylindica* as *B. parviflora.*

Kandelia candel was dominant along Chapora, Mandovi and Zuari estuaries where it was showing Good regeneration. The species was rare along Terekhol estuary and was showing Poor natural regeneration. The species was absent along all other estuaries. *Kandelia candel* was reported by Shinde and Mustafa (1974) to be found only in upstream areas. In the publication of Government of India (Anonymous, 1987), the species was reported only from the coastline of Goa; though Naskar & Mandal (1999) reported *Kandelia candel* from Gushighata (North 24-Paragonas) of the Sunderbans (West Bengal). Luxuriant growth of *Kandelia candel*, along the estuaries of Goa coast, was reported by Untawale *et al.,* (1982). *Kandelia candel,* which was once reported by Blasco (1975) to be on the verge of extinction, was growing in abundance particularly in upstream regions of various estuaries (personal observation). The Forest Department of Goa raised extensive plantations of *Kandelia candel* along the Zuari estuary under my personal supervision, which are well-established (personal observations).

Excoecaria agallocha was present along all the estuaries in Goa. It was dominant along Chapora, Cumbarjua canal, and Talpona and Galgibag estuaries where it was showing Good natural regeneration. It was common along Terekhol, Mandovi and Zuari estuaries and rare along Sal estuary. Jagtap (1985) reported *Excoecaria agallocha* as very common mangrove in Goa.

Ceriops tagal occurred dominantly at Keri along Terekhol estuary where it was showing Good natural regeneration. The species does not occur anywhere else in Goa. Jagtap (1985) and Naskar & Mandal (1999) also reported this species as rare along Terekhol estuary and absent along all other estuaries of Goa.

Aegiceras corniculatum was locally dominant along Talpona estuary where it was showing Good natural regeneration. Large number of plants of *Aegiceras corniculatum* could be seen in abandoned paddy fields along Talpona - Mutal road. It was common along Sal estuary where it was showing moderate natural regeneration. Dagar and Singh (1999) reported this species from all the mangrove bearing states on the west coast of India, however, it is not reported to occur in Laccadive Islands.

Acanthus ilicifolius was dominant along Mandovi, Zuari estuaries and Cumbarjua canal. It was rare along Galgibag estuary and common along all other estuaries.

The species was showing Good natural regeneration along all the estuaries except Galgibag and Terekhol estuaries where it was moderate. Banerjee and Gosh (1998) reported this species from East, West coasts and Andaman & Nicobar Islands.

Derris heterophylla is a climber and dominated along Mandovi, Zuari estuaries and Cumbarjua canal. It was common along all other estuaries. The species was showing Good natural regeneration along Chapora, Zuari, Sal estuaries and Cumbarjua Canal and Poor natural regeneration along Terekhol estuary. Naskar & Mandal (1999) reported this species from Goa and also stated that the species might actually be *D. trifoliata.*

Acrostichum aureum is a fern and common along Terekhol, Chapora, Zuari and Sal estuaries. It was rare along all other estuaries. The species was showing Good natural regeneration along Terekhol, Mandovi, Zuari, Sal estuaries and moderate natural regeneration along Chapora and Talpona estuaries. Untawale *et al.,* (1982) reported this species common along all the estuaries.

Dagar and Singh (1999) reported occurrence of *Sonneratia apetala* and *Xylocarpus granatum* from Goa, which does not seem to be true, as these species were not noticed in Goa during the extensive and intensive field survey.

Naskar & Mandal (1999) reported that during 1993-94 due to construction of the Konkan Railway Bridge on the Zuari estuary at Agassi- Cortalim destroyed several hectares mangrove habitat. Prior to construction of this railway bridge several mangrove species like *Avicennia marina. A. officinalis, Rhizophora mucronata, Excoecaria agallocha, Acanthus ilicifolius, Derris heterophylla* were present in these Agassi- Cortalim region of Zuari estuary. I regularly visited the bridge construction site during 1992-97 and noticed degradation of mangroves in an area of about 4 ha around the site. But after completion of bridge construction and consequently withdrawal of human interference in the area, renewal of forest crop was noticed. Again, I visited the area during 1999 and found profuse natural growth of mangroves around the bridge.

Tables- 2.7, 2.9, 2.11, 2.13, 2.15, 2.17, 2.19 and 2.21 show the data on natural regeneration of mangroves along different estuaries. From these tables it is very clear there are certain species which are basically found towards waterfront zone and there are some other particular species which are found in landward zone. Species found basically in waterfront zone are *Rhizophora mucronata, R. apiculata, Avicennia officinalis, A. marina, A. alba, Sonneratia alba, S. caseolaris, Kandelia candel* and *Ceriops tagal*. The species found basically in landward zone are *Bruguiera gymnorrhiza, B. cylindrica, Excoecaria agallocha, Aegiceras corniculatum, Acanthus ilicifolius, Derris heterophylla and Acrostichum aureum.* Zonation within the mangroves varies from the coastal region towards the headwater while most of the mangroves occur in the bay region near the mouth of the river. Most of the mangroves in the latter area are tall and the stands are dense. In upstream areas the mangroves occur in isolated patches (Untawale *et al*., 1982).

The natural regeneration of *Rhizophora mucronata, Avicennia officinalis, Sonneratia alba, Excoecaria agallocha, Acanthus ilicifolius, Derris heterophylla,* and *Acrostichum aureum* was quite satisfactory (Table-2.23). *Avicennia marina* and *Kandelia candel* were also showing more or less satisfactory natural regeneration but the remaining species i.e. *Rhizophora apiculata, Avicennia alba, Bruguiera gymnorrhiza, B. cylindrica, Ceriops tagal* and *Aegiceras corniculatum* were critical from the point of view of their natural regeneration. Good renewal of forest crop of *Rhizophora apiculata* and *Ceriops tagal*, poor renewal in *Sonneratia alba* and absence of *Kandelia candel* have been reported from Middle Andaman (Kumar, 1998).

TABLE-2.22

RELATIVE DOMINANCE OF MANGROVE SPECIES ALONG ESTUARIES OF GOA

S.N.	Species	Terekhol	Chapora	Mandovi	Zuari	Cumbarjua canal	Sal	Talpona	Galgibag
1	*Rhizophora mucronata*	d	R	d	d	d	d	d	d
2	*Rhizophora apiculata*	a	A	c	a	r	a	a	d
3	*Avicennia officinalis*	d	d	d	d	d	d	d	d
4	*Avicennia marina*	r	r	r	d	c	a	r	c
5	*Avicennia alba*	a	a	r	a	a	d	a	a
6	*Sonneratia alba*	d	d	d	d	r	r	d	d
7	*Sonneratia caseolaris*	r	d	d	d	r	r	a	a
8	*Bruguiera gymnorrhiza*	a	a	r	d*	r	r	d*	r
9	*Bruguiera cylindrica*	a	r	r	r	d*	a	a	a
10	*Kandelia candel*	r	d	d	d	a	a	a	a
11	*Excoecaria agallocha*	c	d	c	c	d	r	d	d
12	*Ceriops tagal*	d*	a	a	a	a	a	a	a
13	*Aegiceras corniculatum*	r	a	r	r	a	c	d*	a
14	*Acanthus ilicifolius*	c	c	d	d	d	c	c	r
15	*Derris heterophylla*	c	c	d	d	d	c	c	c
16	*Acrostichum aureum*	c	c	r*	c	r	c	r	r

INDEX:
a =Absent , r = Rare , c = Common , d = Dominant , * =Locally dominant

TABLE-2.23

COMPARATIVE STATE OF NATURAL REGENERATION OF MANGROVES ALONG DIFFERENT ESTUARIES IN GOA

S.No.	Species	Name of Estuaries							
		Terekhol	Chapora	Mandovi	Zuari	Cumbarjua Canal	Sal	Talpona	Galgibag
1	*Rhizophora mucronata*	G	P	G	G	G	G	M	G
2	*Rhizophora apiculata*	-	-	M	-	P	-	-	G
3	*Avicennia officinalis*	G	G	G	G	G	G	G	G
4	*Avicennia marina*	P	P	P	G	M	-	M	M
5	*Avicennia alba*	-	-	P	-	-	G	-	-
6	*Sonneratia alba*	G	G	G	G	P	P	G	G
7	*Sonneratia caseolaris*	P	G	G	G	P	P	-	-
8	*Bruguiera gymnorrhiza*	-	-	P	G	P	P	G	P
9	*Bruguiera cylindrica*	-	-	P	P	G	-	-	-
10	*Kandelia candel*	P	G	G	G	P	-	-	-
11	*Excoecaria agallocha*	M	G	M	M	G	M	G	G
12	*Ceriops tagal*	G	-	-	-	-	-	-	-
13	*Aegiceras corniculatum*	P	-	P	P	-	M	G	-
14	*Acanthus ilicifolius*	M	G	G	G	G	G	G	G
15	*Derris heterophylla*	P	G	M	G	G	G	M	M
16	*Acrostichum aureum*	G	M	G	G	M	G	M	P

INDEX: G = Good Natural regeneration, M = Moderate Natural regeneration, P = Poor Natural regeneration,
- = Species not significant along the estuary from occurrences point of view.

2.5 CONSERVATION AND MANAGEMENT OF MANGROVES IN GOA

Mangrove afforestation work started in Goa in the year 1985-86 to restore the degraded mangrove areas. By the end of 1996-97 total 876.45 hectares area was covered under Afforestation programme. (Forest Department of Goa)

During January 1988, The State Level Steering Committee was formed by the Government of Goa to oversee the development of mangrove forest in Goa (Government of Goa, Notification No. 8/10/83/FOR dated 16.01.88.)

178 hectare of best mangrove area at Chorao (Goa) was declared as Reserved Forests under section 20 of the Indian Forest Act, 1927 to protect and conserve mangrove forests. (Government of Goa, Notification No.2-22-74-FOR(c) dated 28.04.88.)

Subsequently, during December 1988, this area was declared as Bird Sanctuary under section 18 of the Wild Life (Protection) Act 1972. This sanctuary was named after famous Ornithologist Dr. Salim Ali and is known as Dr. Salim Ali Bird Sanctuary. (Government of Goa, Notification No. 8/10/83/FOR dated 16.12.88.)

During July 1990, Government of Goa set up a Multiple Disciplinary Project Formulation Team to facilitate preparation of a Comprehensive Action Plan for the development of Mangrove eco-system in Goa. (Government of Goa, Notification No. 8/10/83/FOR dated 16.07.90.)

During September 1990, in view of the importance for conserving the estuarine mangrove ecosystem Government of Goa has decided that no construction/ development will be allowed in the area earmarked by the Forest Department for mangrove conservation. (Government of Goa, Letter No. 4-3-4-90-UDD dated 14.07.90.)

On September 11, 1990, Government of Goa declared that 15 mangrove species should not be felled for a period of ten years. (Government of Goa, Notification No. 8/10/83/FOR dated 11.09.90.)

During the year 1991-92, First five- year Mangrove Management Plan for Goa was prepared which was approved by the State Level Steering Committee and subsequently by Government of India. This Management Plan was implemented in Goa with the financial assistance provided by the Government of India. Under the first Plan, it was proposed to take up 100-hectare mangrove plantation for consecutive five years from 1991-92 onwards and this was implemented successfully. On expiry of the period of First five-year Management Plan, a second one was prepared which is under implementation.

In Goa, Forest Department is the nodal agency for the conservation and management of mangroves. In addition to usual mangrove protection works like departmental patrolling, watch and ward etc., the department also seeks people's co-operation in mangrove protection and conservation. Local people residing close to Mangrove Forests have been proved very useful in the protection of these forests. Goa Forest Department also seeks co-operation of the "PRESS" to educate the people regarding importance of the mangroves. Press plays an important role in the protection of the mangrove forests by publishing any illegal activity noticed by it. There are instances when the department sought co-operation of the State Government through Captain of Ports, Block Development Officer etc. to solve the problem of damage of young mangrove seedlings by drag net fishing.

The conservation of mangrove forests and the protection of their genetic resources is one of the most urgent tropical forest management issues we face today. Mangrove forests are fast disappearing for a variety of reasons, the most important of which is the varied demands now being placed on both mangrove trees and habitats. It is clear that the only way to conserve mangrove resources is to reduce the threats to their survival by bringing mangrove ecosystems under sustainable management.

Concerned with this problem particularly in the context of potential changes in sea levels, the International Tropical Timber Organization and the Center for Research on Sustainable Agricultural and Rural Development, Chennai, recommended as follows:

1) Identification of 4 genetic conservation and demonstration sites – 3 in Asia and Oceania and one in Africa.

2) Organization of a trainers' training program for providing high level training to the managers of mangrove genetic resources centers on all aspects of conservation, evaluation, documentation and utilization, and

3) Development of a Mangrove Ecosystem Information System (MEIS).

Phase I of this project is designed to lead to the establishment of a network of Mangrove Genetic Resources Centres with financial support from ITTO, bilateral and multilateral donors and the respective national governments. When such a Network is established, it will function, with reference to exchange of germplasm, strictly in accordance with national regulations.

CHAPTER- 3

MANGROVES OF ANDAMAN AND NICOBAR ISLANDS- A case study of Middle Andaman

CHAPTER- 3

MANGROVES OF ANDAMAN AND NICOBAR ISLANDS- A case study of Middle Andaman

3.1. INTRODUCTION

3.1.1. GENERAL DESCRIPTION

Andaman and Nicobar group of Islands (India) is located in Bay of Bengal between Latitude 6° to 14° North and Longitude 92° to 94° East (Figure-3.1). The islands are around 572 in number and situated on a submerged mountainous hilly range starting from Arakanyoma (Myanmar) in north and Sumatra in south. Total geographical area of the islands is 8249 sq kms and its 86.93% i.e. 7171 sq kms is under forest cover. Mangrove area of Andaman & Nicobar Islands is 777.69 sq kms (Anonymous, 1997). The coastline is about 1962 kms. Population of A & N islands is 2,80,661 while density of population is 34 per sq km. according to 1991 census (Basic Statistics-1996, Andaman & Nicobar Administration). Andaman group of Islands includs 21 inhabited islands with an area of 6408 sq kms. These islands are stretching more or less in north-south direction. The Nicobar group of islands includs 13 inhabited lying in the north - south east direction covering an area of about 1841 sq kms. The Ten Degree Channel (10°North latitude) with a width of 155 kms. from Little Andaman to Car Nicobar Islands separates the two groups of islands.

Middle Andaman Forest Division is situated between the Latitudes 12° 15' and 12° 50' North and Longitude 92° 40' and 93° 50' east. Its total geographical area is 998.44 sq kms out of which 233.95 sq kms are covered with mangroves as per official records of Environmental & Forest Department which amounts to 23.4% of total geographical area of the division. Mangroves are mainly located along various creeks and sheltered areas. Most of the mangroves occur toward eastern side of Middle Andaman main island and comes under territorial jurisdiction of Bajalungta, Bakultala, Rangat, Betapur and Long Island forest ranges. Northern boundary of the division starts from Cape Strachan in the East and ends at Rocky point off Pilot bay in the west. The southern boundary of the division is Homfry Strait, Elphinstone harbour, Mills passage and Andaman Sea. Eastern boundary of the division is Andaman Sea, while western boundary is the Bay of Bengal. Details of Middle Andaman Forest Division have been shown in Figure-3.2. Information on area of islands comprising Middle Andaman Forest Division has been shown in the Table-3.1.

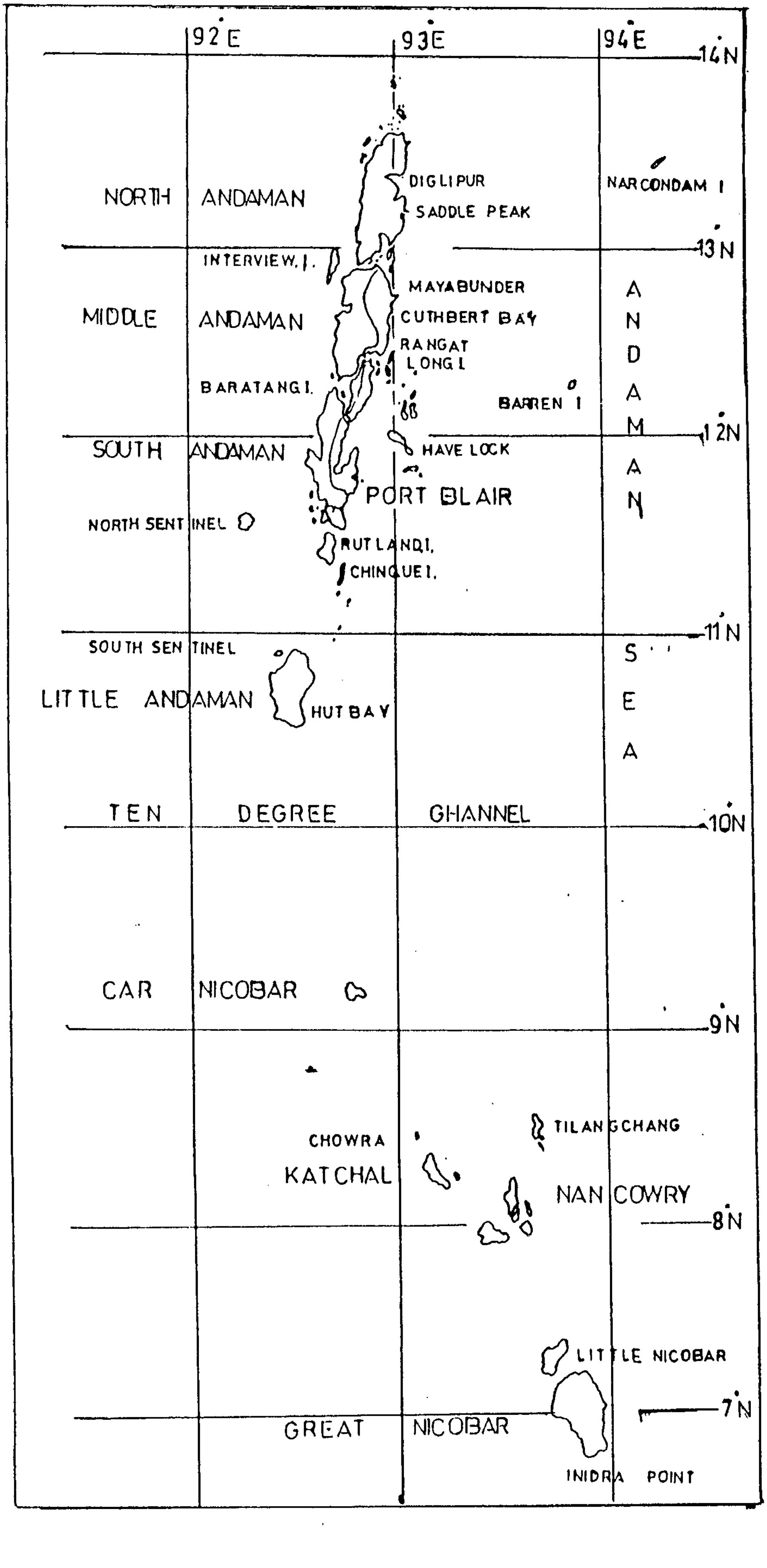


Figure-3.1Map of Andaman and Nicobar Islands

FIGURE- 3.2

MAP SHOWING THE DETAILS OF MIDDLE ANDAMAN DIVISION

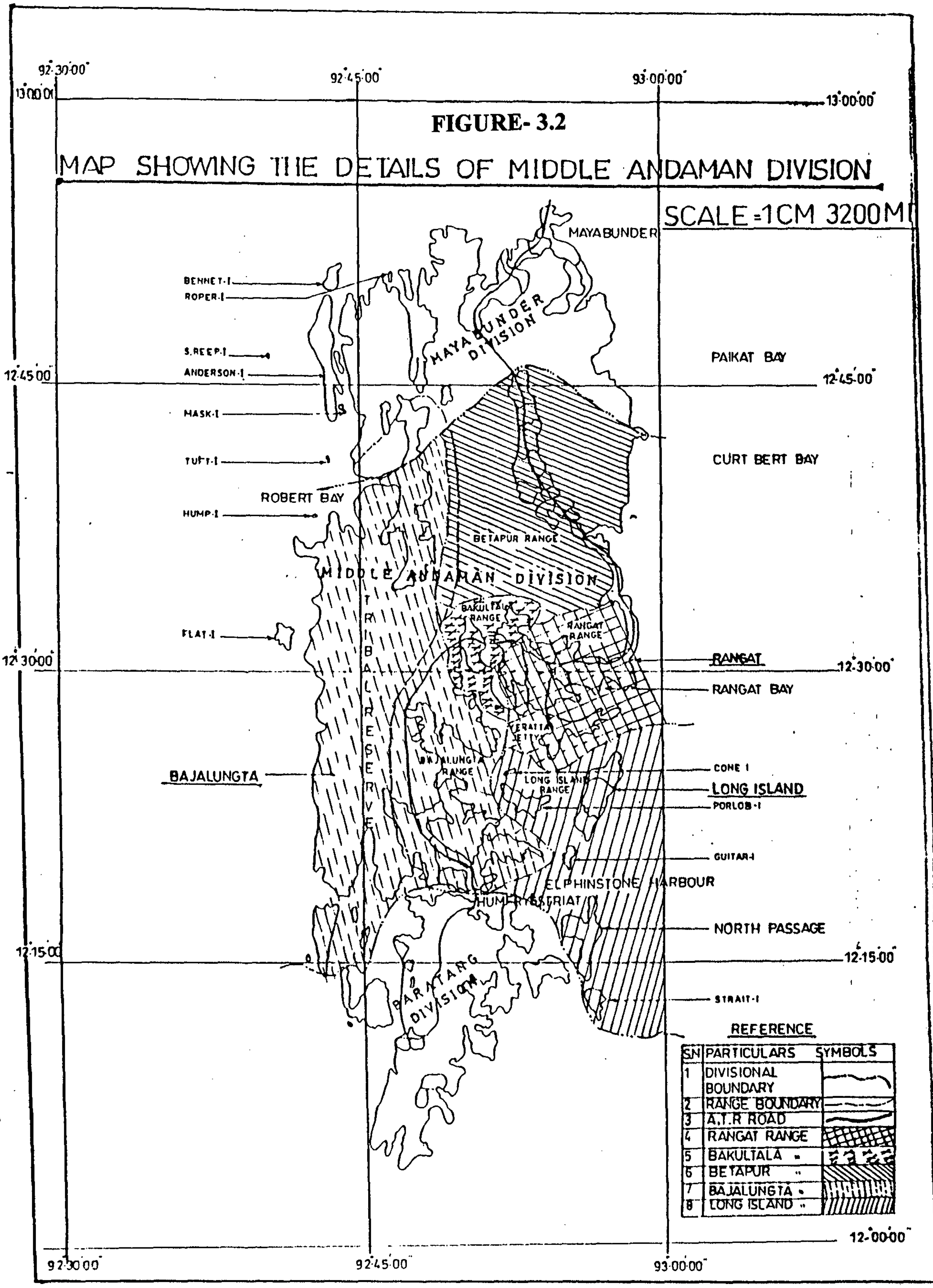


TABLE-3.1

AREA OF ISLANDS COMPRISING MIDDLE ANDAMAN FOREST DIVISION

S.N.	Name of the Island	Forest Range	Geographical Area in ha.
1.*	Southern Part of Middle Andaman Island	Betapur, Rangat, Bakultala, Bajalungta	91,725.00
2.*	Flat Island	Bajalungta	932.00
3.*	Guitar Island	Long Island	263.00
4.*	Porlob Island	Long Island	1,305.00
5.*	Cone Island	Long Island	65.00
6.*	Long Island	Long Island	1,790.00
7.*	North Passage Island	Long Island	2,196.23
8.	Strait Island	Long Island	600.55
9.	South Button Island	Long Island	3.00
10.	Middle Button Island	Long Island	44.00
11.	North Button Island	Long Island	44.00
12.	Parkinson Island	Long Island	34.00
13.	Oyster Island	Long Island	8.00
14.	Round Island	Long Island	23.00
15.	Barren Island	Long Island	811.00
	Total		99,843.78

NOTE: Mangroves occur only around islands shown against S.No's 1 to 7*.

SOURCE: Working plan of Middle Andaman Forest Division (1993-2003).

3.1.2. GEOLOGY AND GEOMORPHOLOGY

Geologically, the Bay Islands constitute an Island arc, that can be separated into two concentric arcs, an outer (western) sedimentary arc comprising major islands of the Andaman and Nicobar and extending to the South East forming Indonesian orogenic belt; and the inner (eastern) volcanic arc showing up above sea level as the conical volcanoes of Narcondum and Barren Islands (Dagar & Singh, 1999). These two are the only true volcanoes known in India. The only mud volcano associated with natural oil and gas seeps known in India is from the Baratang Island. A third island arc to the west of the Andaman-Nicobar Islands is in the process of emergence (Eremenko & Sastri, 1977). The rocks occurring in these islands are marine deposits ranging in age from the Cretaceous to recent. The oldest sedimentary rocks recorded are marble and quartzites. Ultrabasic and basic rocks such as gabbros, peridotites, dunites and serpentinites etc. are widely distributed in North, Middle and South Andaman (Srinivasan, 1978).

Geomorphologically, Andaman and Nicobar Islands are generally hilly and undulating. The main hill range runs from north to south. Highest point in the islands is Saddle peak in North Andaman with a height of 732 meters. Southern most island in the Nicobar group is Mount Thulier with a height of about 642 meters (Dagar *et al.*, 1991). The slopes are moderate to steep and rugged. Flat lands are comparatively rare in Andaman group. The islands of Ritchie's Archipelago, Little Andaman and most of the north and central Nicobar are almost flat with slightly indented coastline, surrounded by coral reefs and shallow seas. Long, narrow stretches of sandy beaches are salient features of the topography in general but in Middle Andaman most of the shores are rocky (personal observation).

3.1.3. CLIMATOLOGY

These islands experience tropical warm and humid climate with no distinct season. The temperature varies between 27°C & 32°C, the humidity remains at an average of 80 percent, while the annual rainfall of 3200 mm (approx.) is received in a span of about 155 rainy days during two spells i.e. South-West monsoon from the month of May to September and the North-East monsoon from November to December. Occasionally these islands experience cyclones in a repetitive cycle of about 50 years.

Mean maximum temperature and mean minimum temperature on the island are 30.03° C and 23.60° C respectively. Relative humidity varies from 70% to 90%. Mean annual rainfall is 300 cms. During 1995 and 1996 rainfall recorded at Long Island (Middle Andaman) was 3308.1 mm and 2378.1 mm respectively. Number of rainy days and rainfall recorded at Port Blair during different years has been shown in Table-3.2.

Average mean (minimum-maximum) temperature at Port Blair varied during 1995 and 1996 were 23.6-30.03°C and 23.8-30.2°C respectively (Table-3.3). Mean humidity at 08.30 hrs and 17.30 hrs during 1996 was 78% and 82% respectively (Table-3.4). During 1996 mean minimum and mean maximum wind speeds at Port Blair were 3.6 kms/hrs and 13.0 kms/hrs respectively (Table-3.5).

TABLE-3.2 NUMBER OF RAINY DAYS AND RAINFALL RECORDED AT PORT BLAIR

Month	1992		1993		1994		1995		1996	
	Rainy days	Rain fall (mm)	Rainy days	Rain fall (mm)	Rainy days	Rain fall (mm)	Rainy days	Rain fall (mm)	Rainy days	Rain fall (mm)
1	2	3	4	5	6	7	8	9	10	11
January	3	144.2	-	-	1	1.1	1	003.2	20	093.7
February	-	-	-	-	2	2.9	2	000.9	2	004.8
March	-	-	1	030.0	6	98.1	3	012.3	-	000.5
April	-	-	-	000.8	3	151.7	2	006.9	10	113.9
May	21	303.3	17	276.2	20	413.2	23	406.2	18	222.2
June	22	479.0	16	339.5	23	577.2	27	734.1	25	806.0
July	23	601.7	24	568.6	29	655.9	26	482.7	-	209.3
August	16	401.0	23	344.7	24	505.9	27	541.4	19	425.4
September	16	422.4	24	553.0	21	788.0	27	349.8	26	656.8
October	21	259.1	23	210.4	12	127.5	19	319.7	-	447.1
November	15	177.9	9	192.2	7	174.9	22	495.5	10	314.6
December	2	005.3	5	027.5	3	16.0	1	005.7	9	178.8
Total	**139**	**2793.6**	**142**	**2542.9**	**151**	**3512.4**	**180**	**3358.4**	**139**	**3473.1**

SOURCE: Basic statistics (1996), Andaman and Nicobar Administration.

TABLE-3.3

TEMPERATURE AT PORT BLAIR

	Mean Maximum Temperature (°C)				Mean Minimum Temperature (°C)			
Month	1993	1994	1995	1996	1993	1994	1995	1996
January	29.0	30.1	29.4	29.2	21.6	23.5	22.8	21.9
February	30.5	30.9	31.0	30.0	21.2	23.7	22.6	23.0
March	31.1	30.9	31.7	31.7	23.1	23.1	23.3	23.5
April	32.4	31.6	33.1	32.5	24.8	23.9	25.3	24.3
May	31.4	31.1	31.5	30.5	25.2	24.5	25.2	24.4
June	30.2	29.1	29.6	29.7	25.6	24.2	24.8	26.4
July	27.9	28.6	29.2	29.4	24.3	22.7	23.7	24.2
August	29.0	28.8	29.0	29.5	24.6	23.4	23.9	23.7
September	28.7	29.0	29.3	29.9	23.8	22.7	23.7	23.0
October	29.5	30.3	29.9	28.7	24.0	22.9	23.8	22.9
November	29.9	30.0	29.8	29.8	24.9	23.9	23.0	23.6
December	29.9	31.0	29.4	29.5	24.3	22.6	22.9	22.8
Average Mean Temperature	**30.0**	**30.1**	**30.2**	**30.03**	**24.0**	**23.4**	**23.8**	**23.6**

SOURCE: Basic statistics (1996), Andaman and Nicobar Administration.

TABLE-3.4

RELATIVE HUMIDITY RECORD AT PORT BLAIR

MONTHS	YEAR									
	1992		1993		1994		1995		1996	
	Mean% 0830 IST	Mean% 1730 IST	Mean% 0830 IST	Mean% 1730 IST	Mean% 0830 IST	Mean% 1730 IST	Mean% 0830 IST	Mean% 1730 IST	Mean% 0830 IST	Mean% 1730 IST
January	77	80	71	72	72	75	71	72	69	72
February	69	69	68	71	70	69	71	71	73	76
March	68	77	69	71	70	74	70	73	67	74
April	67	70	66	70	71	75	68	72	72	75
May	76	80	73	77	82	85	80	84	811	84
June	82	83	79	82	84	85	86	85	85	87
July	83	84	84	84	86	85	84	85	85	86
August	80	85	82	85	85	86	87	87	83	87
September	84	87	84	86	85	87	86	87	82	87
October	81	86	82	86	76	82	82	87	87	91
November	77	79	75	79	76	79	82	87	80	85
December	72	76	70	72	72	75	67	72	76	79
MEAN	**76**	**80**	**75**	**78**	**77**	**80**	**78**	**80**	**78**	**82**

SOURCE: Basic Statistics (1996), Andaman and Nicobar Administration

TABLE-3.5

MONTHLY MEAN WIND SPEED AT PORT BLAIR

(Km/Hrs.)

Month	1992	1993	1994	1995	1996
January	6.8	6.3	5.1	5.7	5.8
February	5.5	5.4	4.0	5.2	5.3
March	5.0	5.3	5.0	3.4	3.6
April	5.7	5.5	4.5	3.6	4.1
May	8.9	6.0	11.3	9.4	10.4
June	19.0	12.5	14.5	12.5	9.1
July	14.5	14.6	17.6	11.2	13.0
August	15.6	15.2	15.8	11.6	1.8
September	10.4	9.2	12.7	11.1	6.4
October	6.5	-	4.6	6.1	11.4
November	7.2	4.0	7.2	7.2	5.8
December	7.7	6.2	6.0	6.2	5.1

SOURCE: Basic Statistics (1996), Andaman and Nicobar Administration

3.1.4. HYDROLOGY

Das and Dev Roy (1989) studied four environmental parameters in Andaman and Nicobar region namely, temperature, salinity, dissolved oxygen and pH. Atmospheric temperature varied from 23.4°C to 31°C, surface (soil) temperature from 27.8°to 35.3°C and temperature of surf water from 27.5° to 34.5°C. The important feature of these temperature readings was that surface (soil) temperature was always higher than atmospheric temperature during the field work. Further in some mangrove areas of South Andaman (*viz.* Corbyn's Cove, Guptapara and Chidyatapu) temperature of some fiddler crab burrows at about 10 cms. depth was also recorded through the year round. These burrow temperatures varied from 28.1° to 31.5°C. The most notable feature of the burrow temperature was that although it was lower than the surface (soil) temperature, still in most cases it was higher than prevailing atmospheric temperature.

Salinity of the estuarine areas of mangrove showed considerable fluctuation, ranging from 1.8 ppt to 31.8 ppt and that of the bays fringed with mangroves varied from 28.6 ppt to 33 ppt, showing very little fluctuation. Dissolved oxygen of the mangrove areas was very low, ranging from 1.70 mg/litre to 5.40 mg/litre in marine condition. pH was found to fluctuate from 6.8 to 7.6 in estuarine condition and 6.8 to 7.8 in marine condition.

Soils of Andaman and Nicobar Islands have been studied by Singh *et al.,* (1988). According to them soils of the valley flats are alluvial in nature, moderately well drained and moderate to very deep. The soils of hill slopes occur either on gentle slopes or uplands near foothills. They are moderately to well drained and have developed from sandstones, shales and other rocks of sedimentary origin. In mangrove areas the soil is saline alluvial.

Data on tidal amplitude at Port Blair shows that the tidal amplitude is of 1.85 m (Table-3.6).

TABLE –3.6

TIDAL AMPLITUDE AT PORT BLAIR

Heights in Meters above datum					
Mean low water neaps	**Mean low water spring**	**Mean low water neaps**	**Mean sea level**	**Mean high water neaps**	**Mean high water spring**
+ 0.23	+ 0.28	+ 0.90	+ 1.21	+ 1.53	+ 2.18

Note 1: For Port Blair Latitude is 11° 41' N, Longitude is 92° 46' E

2: Table datum corresponds to the zero of predictions at all places.

SOURCE: Indian Tide Tables – Part I (1999) Geodetic and Research Branch Survey of India, Dehra Dun.

3.2. MATERIAL AND METHODS

The chapter deals with the following studies conducted within the territorial jurisdiction of Middle Andaman Forest Division:

(a) Distribution of mangrove species in Middle Andaman Forest Division, their relative abundance (e.g. Abundant, Common, Rare) and Zonation in mangroves.

(b) Status of natural regeneration of mangrove species in Middle Andaman Forest Division.

(c) Assessment of total mangrove area in Middle Andaman Forest Division

(d) Assessment of exploitable growing stock, exploitable level, stand structure and density of mangroves

3.2.1. DISTRIBUTION AND ZONATION IN MANGROVES

Four representative sample plots of one-hectare area each were laid down at four different places in each forest range to study distribution and zonation in mangroves. Total enumeration of different species of mangroves was done in each sample plot. Only well established plants were enumerated. Based on the study, mangrove species were categorised as **Dominant, Common,** and **Rare** depending on the number of established plants found in various sample plots along an estuary. If more than 50 established plants were found in atleast any one of the four sample plots along an estuary, it was categorised as Dominant species. Similarly, if the number was found falling within the class intervals 50-25 or 24-1, it was categorised as Common or Rare species respectively. Zonation pattern in mangroves as seen during the course of study was also recorded.

3.2.2. NATURAL REGENERATION IN MANGROVES

To conduct regeneration survey in each forest range, 10 representative sample plots of the size 250m X 4 m. were selected at different locations to cover all the species and their associations. Longer center line of the linear plots was assumed as a transect and 2m X 2 m. size quadrants were laid down on the left and right side of the central line at an interval of 5 m. Thus a total of 35 quadrants were laid down in each plot, and 100 % enumeration of seedlings/ saplings was done in each quadrant. These seedlings were divided into four different height classes viz. 0-30 cms., 31-60 cms., 61-90 cms. and 91-120 cms. and data were recorded accordingly. Natural regeneration of a species was considered good if its minimum three seedlings were found present in each of the four height classes in atleast one sample plot. Similarly natural regeneration of a species was considered moderate if its minimum two seedlings were found present in atleast any three of the four height classes, in atleast one sample plot. All other categories of natural regeneration were put under 'poor'.

For *Acanthus ilicifolius* and *Acrostichum aureum*, number of plants in 0-30 cms. height class only were considered for judging the state of natural regeneration as the height of the mature plant in the above species seldom exceeds 60 cms. This study was confined to 19 important species of mangroves, which are relatively common in Middle Andaman.

3.2.3. ESTIMATION OF AREA UNDER MANGROVES

To ensure realistic estimate with fair degree of accuracy, two different methods were adopted to assess the area under mangroves in Middle Andaman Forest Division.

(a) By Using Toposheets

Toposheets on scale 1:25000 were taken where mangrove vegetation is already marked. Correctness of mangrove vegetation as shown on the map was crosschecked by ground truthing and by estimating the area at few sites by crude method as sample checking. As a result of this exercise, correctness of the mangrove area on toposheets was established. From the toposheets entire mangrove area of the division was traced on a tracing paper. Mangrove areas, which are not shown on the toposheet, were also marked on the map on tracing paper based on field observations. A dot grid was prepared on the tracing paper by marking 25 dots per sq cms. at even spacing. Dot grid matrix was placed on the toposheet and the number of dots were counted which fell within the mangrove area. Under this method one dot is equivalent to 0.25 ha. By using this formula, the area under mangrove vegetation was calculated.

(b) By Remote Sensing Map and Dot Grid

Satellite imagery (scale 1:1,25,000) prepared by Indian Institute of Remote Sensing, Dehradun was visualised for obtaining the area under mangrove cover. A dot grid used in the above cited method (a) was utilised again to assess the mangrove area. Under this method one dot is equivalent to 6.25 ha. By using this formula, the area under mangrove vegetation was calculated.

3.2.4. ESTIMATION OF EXPLOITABLE GROWING STOCK AND STAND STRUCTURE OF MANGROVES

In order to assess the exploitable growing stock of mangroves in each range 10 representative sample plots of the size 250m X 4 m. were selected at different locations. Location of plot and its vegetation was selected for sampling in such a way to have fair idea about the average growing stock. 100 % enumeration was done in each sample plot in respect of all those species, which have the potential for yielding firewood and timber.

Linear plots were selected as mangrove vegetation is generally found in a narrow strip of varying width along the creeks. All the trees falling within the sample plot were given serial number and their GBH (ob) i.e. girth overbark at breast height (1.37 m) and tree-height were recorded. Girth was recorded by using measuring tape. Abneys Level was used to measure the height of trees. But wherever plant height was so less that it could be read on a scale ocularly, a graduated wooden bar was used to record the height of the plant. Volume of the trees was calculated without taking taper into account, on the basis of cylindrical cross section at breast height. It was assumed that this would take care of volume contained in branches of the tree.

All the trees having GBH (ob) above 50 cm. were considered for putting in the category of exploitable growing stock and their sample plot wise and forest range wise volume was calculated.

In order to study the Stand Structure in different representative sample plots, the above-recorded data was re-structured. In respect of each sample plot, the total number of stems were segregated in different girth classes of 10 cms. interval starting from 0-10 cms, to 91-100 cms. One more girth class was created to record the number of stems above 100-cms girth. On the basis of this exercise forest range wise tables were prepared on stand structure and growing stock of mangroves.

3.3. RESULTS

3.3.1. DISTRIBUTION AND ZONATION IN MANGROVES

Although Dagar *et al.*, (1991) reported about 30 mangrove species from Middle Andaman but this study was confined to 19 important species of mangroves, which are relatively common in Middle Andaman. Data collected on distribution of mangroves in five different forest ranges have been shown in Tables-3.7 to 3.11. It can be seen that all the species do not occur at any particular location. Moreover, relative abundance of a particular species is also not uniform throughout the forest range. It varies from place to place within the range itself. Following are some special observations noted during the course of study:

a) All along the estuaries and creeks continuous strips of *Rhizophora* could be seen towards water front side. *Rhizophora apiculata* was most abundant and occurs almost in pure patches. Pure patches of *Rhizophora mucronata* were much less compared to *R. apiculata*. At some places these two species also co-existed. *Rhizophora* plants, which were just adjacent to the waterfront, were short in height, branchy, with well-developed crown and produced large number of propagules. This character ensured their stability in the prevailing environment and dispersion of propagules to distant places through water.

Rhizophora plants in the middle zone were very tall, with few branches towards upper side only, with well-developed cylindrical bole and produced lesser number of propagules. Stands consisting of tall *Rhizophora* trees about 30-35 meters high with cylindrical bole were common in Middle Andaman. *Rhizophora* is also important from commercial point of view.

b) Tall trees of *Bruguiera gymnorrhiza* were abundant and also important from commercial point of view. Fully-grown trees varied in height from 25-35 meters.

c) *Ceriops tagal* is a small to medium sized tree and noted in abundance in various parts of Middle Andaman. There are areas in the division where there is exceptionally high concentration of this species. Although the tree is not very important from commercial point of view, it can yield little fuelwood to meet small demand of local people. In interior areas of Yerrata (Middle Andaman), some tall trees with height up to 15 meters with cylindrical boles were noticed.

Ceriops tagal plants, which were just adjacent to the open land area, were short in height, branchy, with well-developed crown and produced large number of propagules while the plants in the inner part of middle zone were tall, with few branches towards upper side only, with well developed cylindrical bole and produced lesser number of propagules.

d) *Avicennia officinalis* and *A. marina* trees occurred in a scattered manner but at few places like Uttara, Nimbutala, Lalajibay, big patches of almost pure *Avicennia* were seen. At most of the places *Avicennia marina* plants were adversely affected due to cattle pressure, as its leaves are palatable. Occasionally, trees with large girth were seen, which could have been exploited for firewood. Hollowness was common in overmature trees.

e) *Sonneratia alba* and *S. caseolaris* were rarely found in Middle Andaman.

f) Towards landward side *Phoenix paludosa*, *Excoecaria agallocha*, *Acrostichum aureum*, *Heritiera littoralis* were very common. *Phoenix paludosa* was common in muddy areas. *Acrostichum aureum* and *Phoenix paludosa* were very commonly seen regenerating naturally on the mounds made by crabs.

g) *Lumnitzera littorea* was common in Middle Andaman but *Lumnitzera racemosa* was rare. *Lumnitzera littorea* was found exceptionally abundant in some areas. These species were commonly seen regenerating naturally on the mounds made by crabs.

h) *Aegiceras corniculatum* was rare in Middle Andaman except in some places like Uttara, where large number of plants could be seen in a limited area.

I) Species like *Xylocarpus granatum* and *X. moluecensis* were fairly common and found both towards water front and landward side. As these trees were found scattered, they are not important for commercial exploitation. Some people were seen collecting fruits of these species illegally for ultimately exporting to mainland. This was probably for its use for manufacture of some medicine.

j) The mangrove palm *Nypa fruticans* occurs towards landward side. However, it is not evenly distributed in Middle Andaman. There are areas like Dhaninallah where the species occurs in pure patches. The species is under pressure as its leaves are most preferred for thatching and local people eat kernels of young fruits. *Nypa fruticans* was common noticed in muddy areas.

Zonation in mangroves has been shown in the Table-3.12. During the course of study three distinct zones were consistently seen viz. Water front Zone, Middle Zone and Landward Zone. There were some species, which were not confined to any particular zone but occurred in more than one zone. Distribution of mangroves in various zones was largely governed by the soil salinity.

TABLE-3.7

MANGROVE DISTRIBUTION IN BAJALUNGTA FOREST RANGE

S.N.	Name of the Species	Number of established plants per hectare at different locations			
		Dhani-nallah	Uttara Village	Uttara Jetty	Homfry Strait
1.	*Rhizophora apiculata*			563	55
2.	*Rhizophora mucronata*				866
3.	*Bruguiera gymnorrhiza*			76	
4.	*Ceriops tagal*			213	
5.	*Avicennia officinalis*	268	350	26	
6.	*Avicennia marina*	30	48	47	
7.	*Excoecaria agallocha*	41	40	8	
8.	*Acrostichum aureum*	111	129	19	
9.	*Lumnitzera littorea*			244	
10.	*Xylocarpus granatum*				37
11.	*Xylocarpus moluecensis*				28
12.	*Nypa fruticans*	448			
13.	*Phoenix paludosa*	306	345	21	
14.	*Heritiera littoralis*		37	10	
15.	*Aegiceras corniculatum*		48		
16.	*Sonneratia alba*				20
17.	*Sonneratia caseolaris*				
18.	*Acanthus ilicifolius*		5		
19.	*Lumnitzera racemosa*		8		

Note: Blank blocks represent the figure "zero"

TABLE-3.8

MANGROVE DISTRIBUTION IN BAKULTALA FOREST RANGE

S.N.	Name of the Species	Number of established plants per hectare at different locations			
		Shyam Kund	Shyam Kund	Bakul tala	Kaushalya nagar
1.	*Rhizophora apiculata*	478	158	306	
2.	*Rhizophora mucronata*	11	570	188	
3.	*Bruguiera gymnorrhiza*	240	202	191	18
4.	*Ceriops tagal*				
5.	*Avicennia officinalis*	42			405
6.	*Avicennia marina*	16			20
7.	*Excoecaria agallocha*	39		46	42
8.	*Acrostichum aureum*			38	40
9.	*Lumnitzera littorea*	14			
10.	*Xylocarpus granatum*	55	37		
11.	*Xylocarpus moluecensis*		31		
12.	*Nypa fruticans*				
13.	*Phoenix paludosa*			49	29
14.	*Heritiera littoralis*	44		35	31
15.	*Aegiceras corniculatum*			5	
16.	*Sonneratia alba*	9			
17.	*Sonneratia caseolaris*			11	
18.	*Acanthus ilicifolius*	10		17	
19.	*Lumnitzera racemosa*		9		

Note: Blank blocks represent the figure "zero"

TABLE-3.9

MANGROVE DISTRIBUTION IN RANGAT FOREST RANGE

S.N.	Name of the Species	Number of established plants per hectare at different locations			
		Yerrata Jetty	Yerrata	Goal pahar	Nimbu tala
1.	*Rhizophora apiculata*	850	606	804	
2.	*Rhizophora mucronata*	41	29	40	
3.	*Bruguiera gymnorrhiza*	277	150	216	
4.	*Ceriops tagal*	396	172	311	150
5.	*Avicennia officinalis*				6
6.	*Avicennia marina*				702
7.	*Excoecaria agallocha*		30	42	33
8.	*Acrostichum aureum*		27	33	29
9.	*Lumnitzera littorea*				20
10.	*Xylocarpus granatum*		30		
11.	*Xylocarpus moluecensis*		27		
12.	*Nypa fruticans*				
13.	*Phoenix paludosa*	61	55		66
14.	*Heritiera littoralis*	10	33		15
15.	*Aegiceras corniculatum*			7	
16.	*Sonneratia alba*			6	
17.	*Sonneratia caseolaris*			4	
18.	*Acanthus ilicifolius*				8
19.	*Lumnitzera racemosa*			14	

Note: Blank blocks represent the figure "zero"

TABLE-3.10

MANGROVE DISTRIBUTION IN BETAPUR FOREST RANGE

S.N.	Name of the Species	Number of established plants per hectare at different locations			
		Dhani nallah	Dhani nallah	Dhani nallah	Dhani nallah
1.	*Rhizophora apiculata*	49			36
2.	*Rhizophora mucronata*	21			20
3.	*Bruguiera gymnorrhiza*	45		46	31
4.	*Ceriops tagal*	810		59	262
5.	*Avicennia officinalis*			6	
6.	*Avicennia marina*			410	
7.	*Excoecaria agallocha*			20	
8.	*Acrostichum aureum*		13		
9.	*Lumnitzera littorea*				12
10.	*Xylocarpus granatum*		20		
11.	*Xylocarpus moluecensis*				
12.	*Nypa fruticans*		895		
13.	*Phoenix paludosa*			46	48
14.	*Heritiera littoralis*			15	
15.	*Aegiceras corniculatum*				
16.	*Sonneratia alba*				
17.	*Sonneratia caseolaris*	6			
18.	*Acanthus ilicifolius*			9	
19.	*Lumnitzera racemosa*			10	

Note: Blank blocks represent the figure "zero"

TABLE-3.11

MANGROVE DISTRIBUTION IN LONG ISLAND FOREST RANGE

S.N.	Name of the Species	Number of established plants per hectare at different locations			
		Porlob Island	Porlob Island	Mark Bay	Lalaaji Bay
1.	*Rhizophora apiculata*	300	104	292	91
2.	*Rhizophora mucronata*	16	283		
3.	*Bruguiera gymnorrhiza*	6	3	22	
4.	*Ceriops tagal*	162	100	19	26
5.	*Avicennia officinalis*	9			285
6.	*Avicennia marina*		32		45
7.	*Excoecaria agallocha*	6	41		10
8.	*Acrostichum aureum*	18	6		
9.	*Lumnitzera littorea*		73		
10.	*Xylocarpus granatum*				6
11.	*Xylocarpus moluecensis*				
12.	*Nypa fruticans*				
13.	*Phoenix paludosa*	151	60	31	41
14.	*Heritiera littoralis*	13		16	
15.	*Aegiceras corniculatum*				
16.	*Sonneratia alba*	11	6		
17.	*Sonneratia caseolaris*				
18.	*Acanthus ilicifolius*			10	
19.	*Lumnitzera racemosa*	22	20		

Note: Blank blocks represent the figure "zero"

TABLE-3.12

ZONATION IN MANGROVES OF MIDDLE ANDAMAN

S.No.	Name of the Species	Water Front Zone	Middle Zone	Landward Zone
1.	*Rhizophora apiculata*	p	p	
2.	*Rhizophora mucronata*	p	p	
3.	*Sonneratia alba*	p		
4.	*Xylocarpus granatum*	p		p
5.	*Xylocarpus moluecensis*	p		p
6.	*Sonneratia caseolaris*	p	p	
7.	*Avicennia officinalis*	p		p
8.	*Avicennia marina*	p		p
9.	*Bruguiera gymnorrhiza*		p	
10.	*Ceriops tagal*		p	
11.	*Lumnitzera littorea*		p	
12.	*Lumnitzera racemosa*		p	
13.	*Excoecaria agallocha*			p
14.	*Acrostichum aureum*			p
15.	*Nypa fruticans*			p
16.	*Phoenix paludosa*			p
17.	*Heritiera littoralis*			p
18.	*Aegiceras corniculatum*			p
19.	*Acanthus ilicifolius*			p

Index: p = Presence in different zones

3.3.2. NATURAL REGENERATION IN MANGROVES

Natural regeneration in mangrove forest occurs in the form of plants of varying heights, which increase with age. A mangrove plant above 90 cms height can be considered as well established regenerating plant. Data collected as per methodology described in respect of forest ranges has been given in Tables-3.13 to 3.17. Overall natural regeneration pattern in mangroves in different forest ranges have been depicted in the Figures-3.3 to 3.7. The information has been analyzed and discussed in later part of this chapter.

TABLE-3.13 NATURAL REGENERATION OF MANGROVES IN BAJALUNGTA FOREST RANGE

		Number of Plants in Different Height Classes(in CMs)																																							
S. No:	Location	Dhaninallah				Uttara Vill.				Uttara jetty				Uttara Jetty				Uttara Jetty				Uttara Jetty				Homfry St.				Homfry St.				Homfry St.				Homfry St.			
	Zone	Landward				Landward				Landward				Landward				Middle				Waterfront				Waterfront				Landward				Waterfront				Waterfront			
	Plot No:	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10
	Height Classes	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
	Species																																								
1	Rhizophora apiculata									4		2	6					12	6	7	6	49	21	27	14	31	17	3	6									6	4		1
2	Rhizophora mucronata																									10		4						56	43	21	24	36	20	14	20
3	Bruguiera gymnorhiza									4	1		2					4			4	5			1					16			4								
4	Avicennia officinalis	5	2	6	8	22	10	15	8	6	4	4	1	6	2		1																								
5	Avicennia marina	4			5	10	8	6	8	3	2		6					19	11	6	1								1												
6	Phoenix paludosa	10	8	9	4	12	6	6	7	5	6	6	8			2	2														2	10	14								
7	Ceriops tagal									29	20	12	15	32	18	10	10		4	3	1	7	1	4						10	14	14	6								
8	Lumnitzera littorea									18	4	11	15	26	10	10	15	4		1																					
9	Acrostichum aureum	11				21				4				3																											
10	Excoecaria agallocha	5		2	4			4	4			2	4				1																4								
11	Aegiceras corniculatum					18	10	10	14																																
12	Nypa fruticans	6	5	3	8																																				
13	Heritiera littoralis				2			2	1		2		1																		2	1									
14	Sonneratia alba																									3		4	3		4	3	4					4			2
15	Xylocarpus granatum																												2	4	2								2		1
	Total	41	15	20	31	83	34	43	42	73	39	37	58	67	30	22	29	39	21	17	12	61	22	31	15	44	17	11	12	30	24	28	32	56	43	21	24	46	26	14	24
	Index for Height Classes in CMs: A=0-30: B=31-60: C=61-90: D=91-120																																								
	Blank spaces against a particular species indicates its absence in particular height class																																								

Figure-3.3 Overall natural regeneration pattern in Mangroves of Bajalungta Forest Range

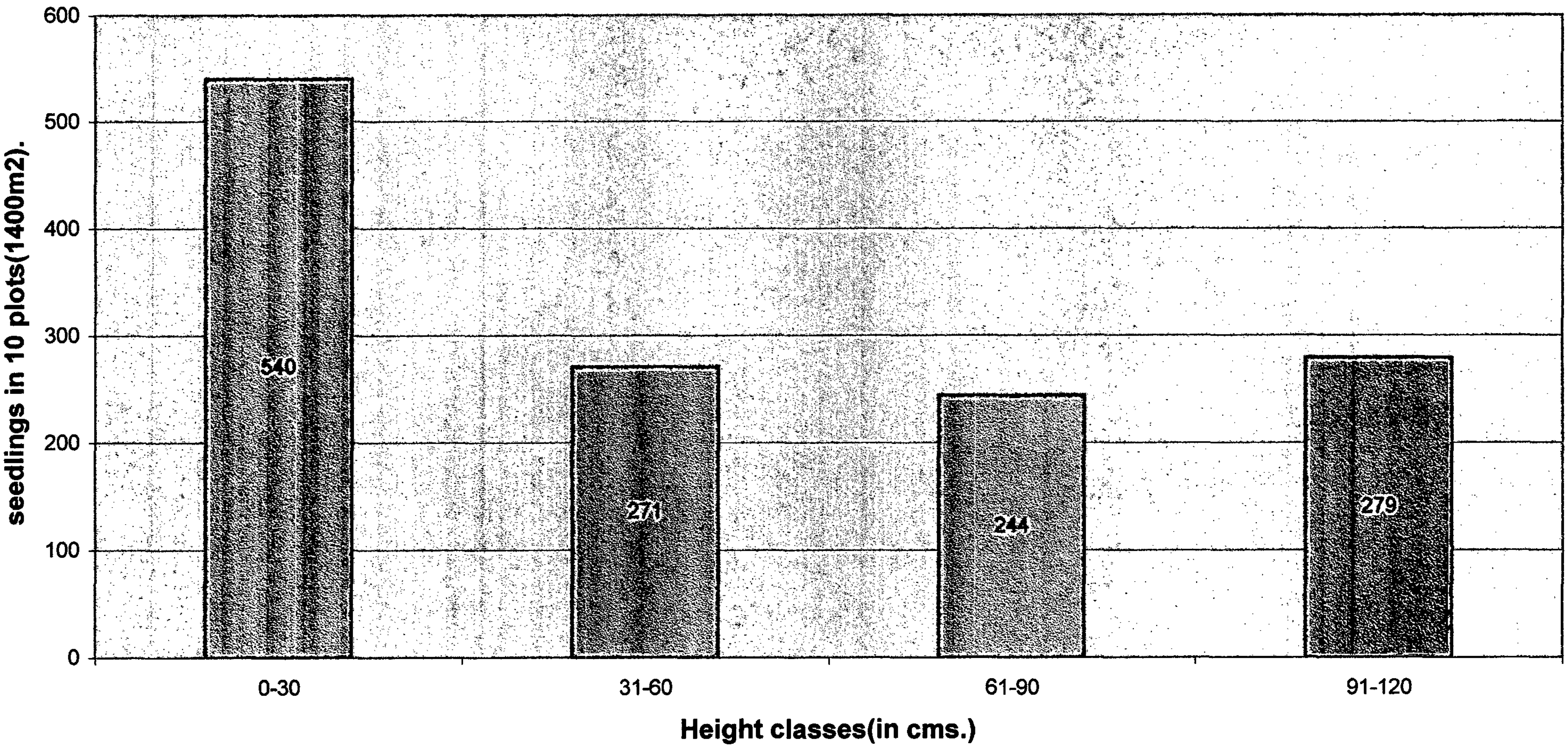


TABLE-3.14 NATURAL REGENERATION OF MANGROVES IN BAKULTALA FOREST RANGE

Number of Plants in Different Height Classes(in CMs)

	Location	Shyamkund				Shyamkund				Shyamkund				Shyamkund				Shyamkund			
	Zone	Waterfront				Landward				Waterfront				Middle Zone				Middle Zone			
	Plot No:	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
	Height Classes	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S. No:	Species																				
1	Rhizophora apiculata	62	32	51	19					10	3			15	9	5	2	31	21	16	9
2	Rhizophora mucronata									82	52	25	20	10	9		3	20	14	9	2
3	Bruguiera gymnorhiza	12	4	7	1					3		2		56	47	19	15	25	20	19	9
4	Excoecaria agallocha					10	12	9	8												
5	Heritiera littoralis					10	6		2												
6	Phoenix paludosa																				
7	Acrostichum aureum																				
8	Avicennia officinalis	21	11	7																	
9	Avicennia marina					12	3	4	6												
10	Sonneratia alba		1		2																
11	Sonneratia caseolaris																			2	6
12	Ceriops tagal					6		1													
13	Xylocarpus granatum																				
14	Xylocarpus moluecensis																				
15	Lumnitzera littorea					18	10	5	8												
16	Lumnitzera racemosa																				
17	Acanthus ilicifolius					7								3							
	Total	95	48	65	22	63	31	19	24	95	55	27	20	84	65	24	20	76	55	44	20

	Location	Shyamkund				Bakultala				Bakultala				Bakultala				K.Nagar			
	Zone	Lanward				Middle Zone				Landward				Waterfront				Landward			
	Plot No:	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10
	Height Classes	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S. No:	Species																				
1	Rhizophora apiculata					31	20	13	5		6			22	12	12	3				
2	Rhizophora mucronata													8	6	4	4				
3	Bruguiera gymnorhiza					26	16	15	6	26	17	20	16	18	16	10	7				
4	Excoecaria agallocha	10	6	5	4					13	10	7	4							4	2
5	Heritiera littoralis	5	5		1					16	9	7	6					1		2	
6	Phoenix paludosa	25	12	11	8					57	49	29	29					5	4	6	8
7	Acrostichum aureum	9	6							76	57							15	4		
8	Avicennia officinalis	29	16	9	3										2			41	28	14	20
9	Avicennia marina																	26	18	20	15
10	Sonneratia alba																				
11	Sonneratia caseolaris					6			2					6	2						
12	Ceriops tagal	3																			
13	Xylocarpus granatum																				
14	Xylocarpus moluecensis	1		4	1																
15	Lumnitzera littorea	8	7	1	4																
16	Lumnitzera racemosa															6	2				
17	Acanthus ilicifolius	6								5											
	Total	96	52	30	21	63	35	28	13	193	148	63	55	54	38	32	16	88	54	46	45

Index for Height Classes in Cms: A=0-30; B=31-60; C=61-90; D=91-120

Blank space against a particular species indicates its absence in particular height class

Figure-3.4 Overall natural regeneration pattern in Mangroves of Bakultala Forest Range

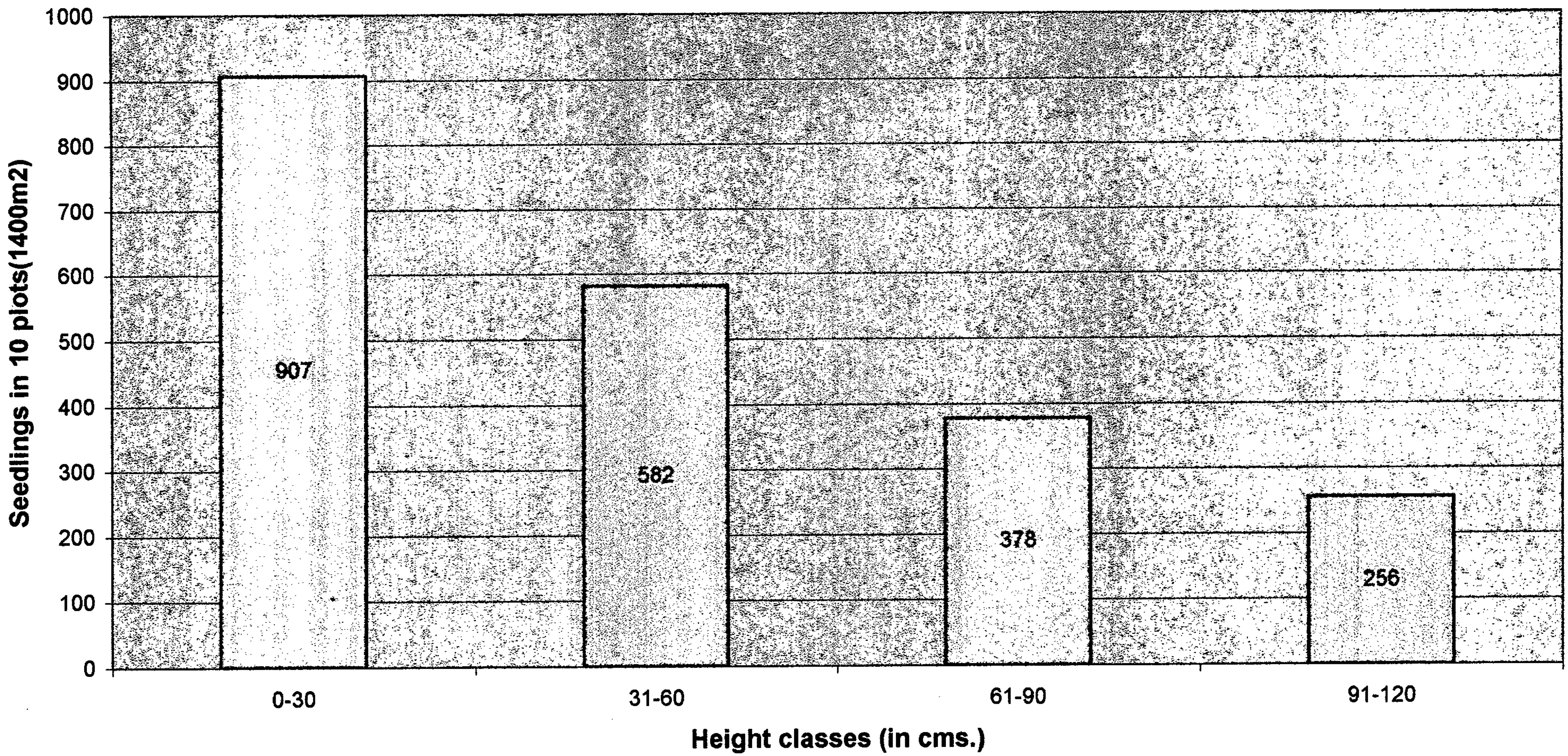


TABLE-3.15 NATURAL REGENERATION OF MANGROVES IN RANGAT FOREST RANGE

	Number of Plants in Different Height Classes(in CMs)																																								
—	Location	Yeratta Jetty				Yoljig creek				Udislie creek				Goltikry				Yerretta				Bharatpur				Goalpahar				Goalpahar				Goalpahar				Nimbutala			
	Zone	Waterfront				Waterfront				Middle Zone				Waterfront				Landward				Landward				Waterfront				waterfront				Landward				Landward			
	Plot No:	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10
	Height Classes	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S.N.	Species																																								
1	Rhizophora apiculata	68	30			2				3				67	78	9			1	2						72	55	39	24	34	60	9	3	61	96	6	13				
2	Rhizophora mucronata													4												4				1											
3	Bruguiera gymnorhiza	3	10	2		12	4		1	3	10	11	1						2			1	4	3		3	2	1	1	25	16		9	6							
4	Ceriops tagal			1		18	1			5	8			40		2					2					61	74	56	52	71	61	3	27	40	24	2	6	54	30	63	26
5	Phoenix paludosa																	10	10	9	12		6	10	11															6	6
6	Avicennia marina																																					124	90	29	16
7	Excoecaria agallocha																	6	2	4	6		4	6	7									4	2		4	6	1	10	12
8	Heritiera littoralis			3																2	3		2																	2	
9	Xylocarpus granatum																		1	3																					
10	Xylocarpus moluecensis																							1	2																
11	Lumnitzera littorea																		4	1	2																	27	18		
12	Lumnitzera racemosa																		3																2						
13	Sonneratia alba								1																																
14	Sonneratia caseolaris																							6	4						2		1				3				
15	Acrostichum aureum																					15								14	10			10	16			41			
	Total	71	40	6		32	5		2	11	18	11	1	111	78	11		16	23	21	25	16	16	26	24	140	131	96	77	145	149	12	40	121	140	8	26	252	139	110	60

Index for Height Classes in Cms: A=0-30: B=31-60: C=61-90: D=91-120

Blank space against a particular species indicates its absence in particular height class.

Figure-3.5 Overall natural regeneration pattern in Mangroves of Rangat Forest Range

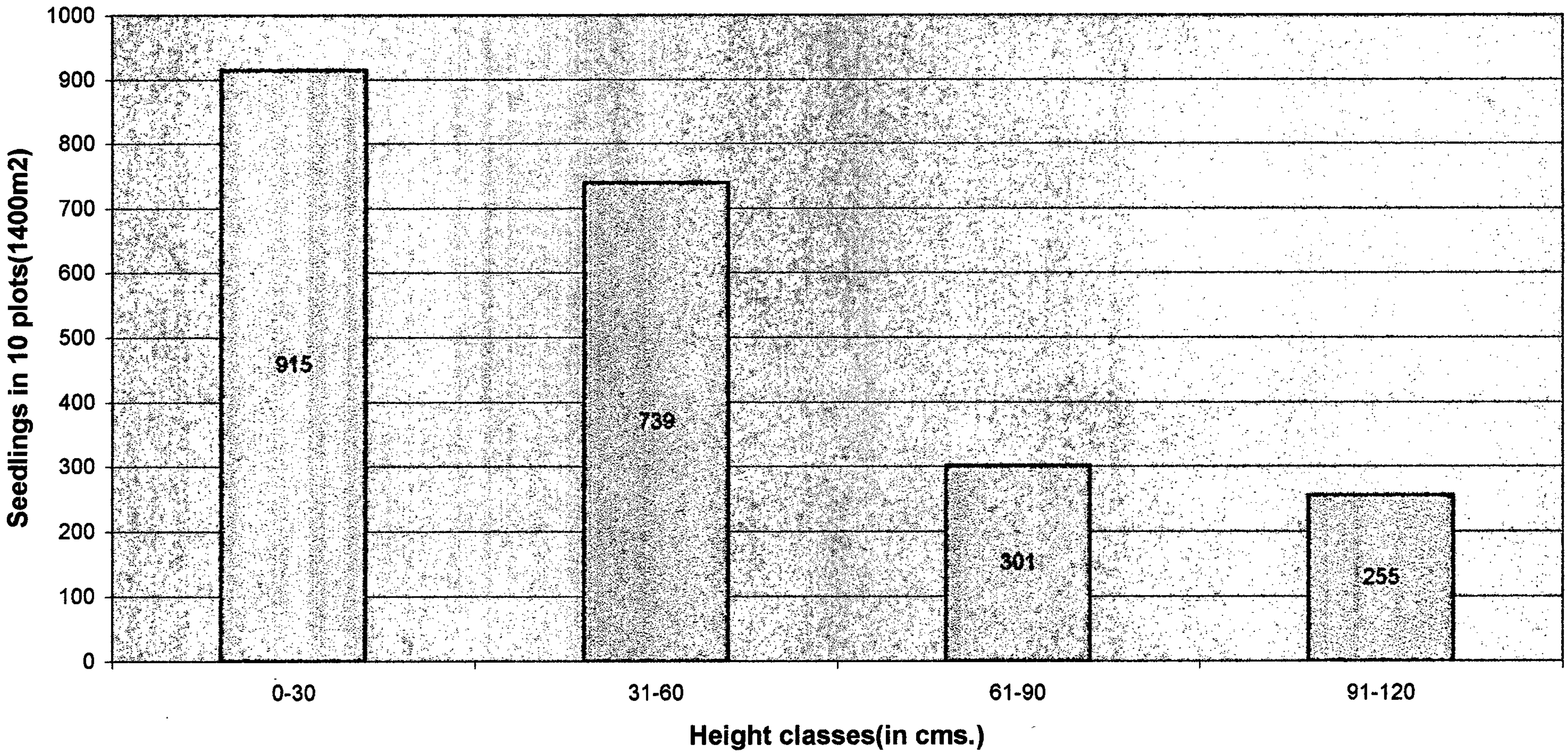


TABLE-3.16 NATURAL REGENERATION OF MANGROVES IN BETAPUR FOREST RANGE

															Number of Plants in Different Height Classes(in CMs)						
	Location	Dhaninallah				Dhaninallah				Dhaninallah					Dhaninallah				Dhaninallah		
	Zone	Landward				Landward				Middle Zone					Landward				Middle Zone		
	Plot No:	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
	Height Classes	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S. No:	Species																				
1	Ceriops tagal	101	137	52	190	43	76	17	87	60	44	21	63					2	4		3
2	Avicennia marina									18	6		2	23	33	4	1				
3	Nypa fruticans				3												11				
4	Rhizophora apiculata	5	10			3	4		5		2		1					11	11	1	
5	Bruguiera gymnorhiza	1											2	6	2		7	4	8		2
6	Rhizophora mucronata				2					3	18							3	4	1	1
7	Heritiera littoralis	1																			
8	Excoecaria agallocha																				
9	Lumnitzera littorea																	9		6	
10	Phoenix paludosa																	20	16	9	18
11	Sonneratia caseolaris													9	6		2				
12	Acrostichum aureum													16				2			
	Total	108	147	52	195	46	80	17	92	81	70	21	68	54	41	4	21	51	43	17	24

	Location		Dhaninalla			Dhaninallah				Dhaninallah				Dhaninallah				Dhaninallah			
	Zone		Waterfront			Landward				Landward				Landward				Landward			
	Plot No:	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10
	Height Classes	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S. No:	Species																				
1	Ceriops tagal	1				8	17	16	68	2	1	1						7			
2	Avicennia marina									22	24	6	2					3	4	3	2
3	Nypa fruticans						2	3	12						1		39				21
4	Rhizophora apiculata	2	4		1	13	20		2					3	6			6	10		
5	Bruguiera gymnorhiza	4	20	1	6				1				1		17	6	1		1		
6	Rhizophora mucronata		4																6		
7	Heritiera littoralis																			1	
8	Excoecaria agallocha									8		2	1								
9	Lumnitzera littorea																				
10	Phoenix paludosa							1	7												5
11	Sonneratia caseolaris																				
12	Acrostichum aureum																				
	Total	7	28	1	7	21	39	20	90	32	25	9	4	3	24	6	40	16	21	4	28

Index for Height Classes in Cms: A=0-30; B=31-60; C=61-90; D=91-120.

Blank space against a particular species indicates its absence in particular height class

Figure-3.6 Overall natural regeneration pattern in Mangroves of Betapur Forest Range

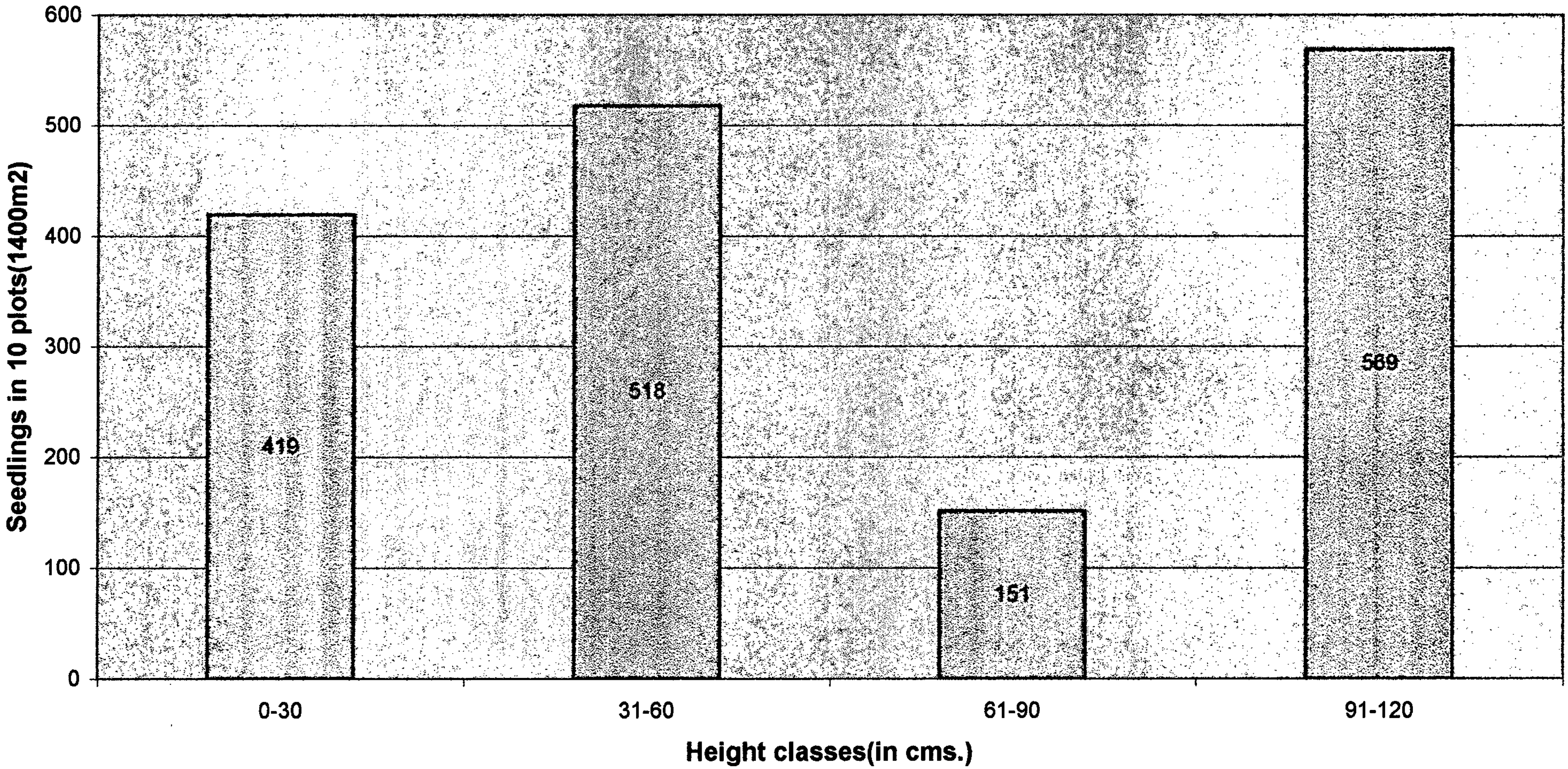


TABLE-3.17 NATURAL REGENERATION OF MANGROVES IN LONG ISLAND FOREST RANGE

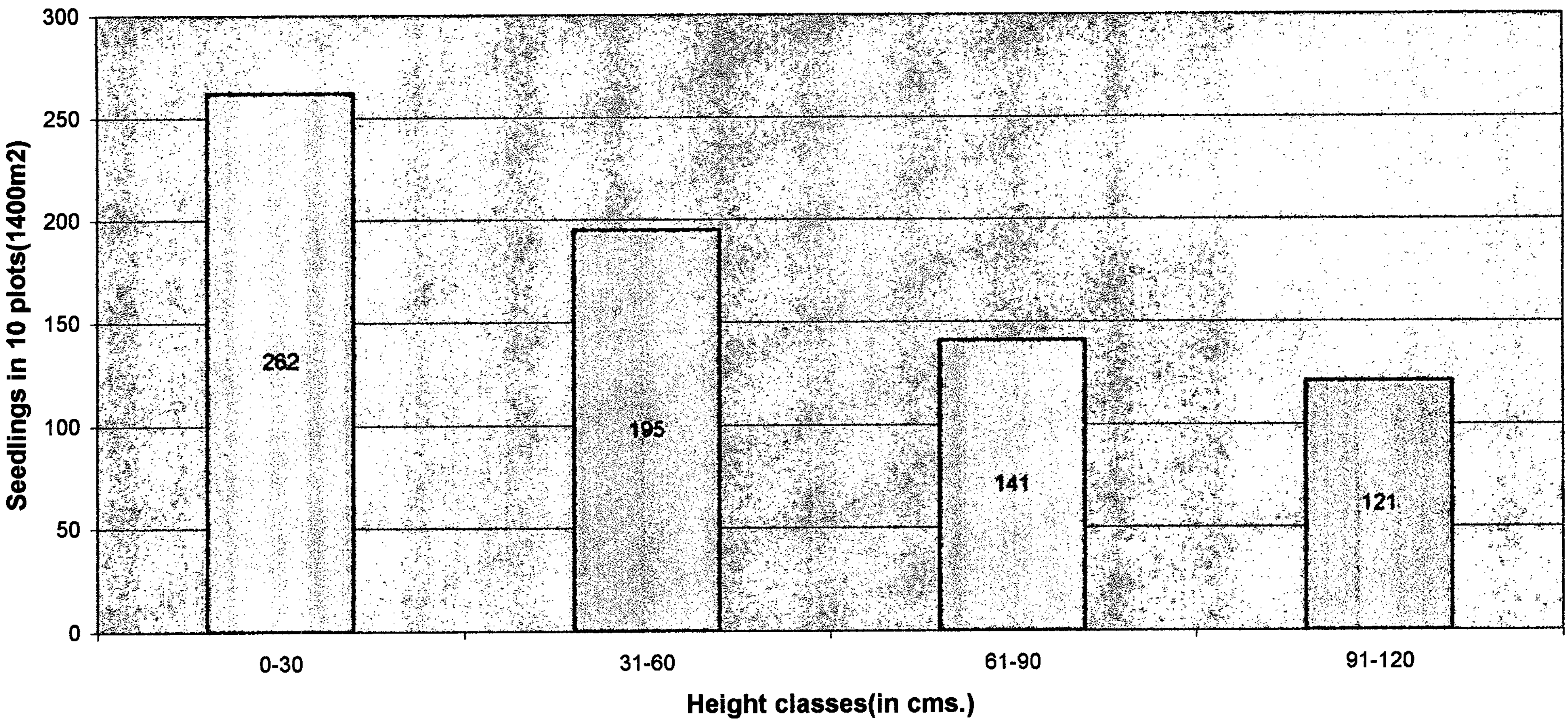
															Number of Plants in Different Height Classes(in CMs)						
	Location	Porlob Island				Porlob Island				Porlob Island					Porlob Island				Porlob Island		
	Zone	Waterfront				Landward				Waterfront					Middle Zone				Landward		
	Plot No:	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
	Height Classes	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S. No:	Species																				
1	Rhizophora apiculata	6	4	6	3					40	21	10	15	11	7						
2	Rhizophora mucronata		2	3												4	3				
3	Ceriops tagal					11	12	6	7									11	11	2	6
4	Lumnitzera racemosa					10	4	6	12									10	5	6	4
5	Phoenix paludosa					4	4	2	1									9	9	7	5
6	Excoecaria agallocha						2											1	2		
7	Avicennia officinalis	2	4																		
8	Avicennia marina														2	2	2				
9	Sonneratia alba	4		1	2																
10	Bruguiera gymnorhiza		2		1									6	2		1				
11	Heritiera littoralis							2													1
	Total	12	12	10	6	25	22	16	20	40	21	10	15	17	11	6	6	31	27	15	16

	Location		Porlob Island			Mark Bay				Mark Bay				Lalaaji Bay				Lalaaji Bay			
	Zone		Waterfront			Waterfront				Landward				Waterfront				Landward			
	Plot No:	6	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10	10	10	10
	Height Classes	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
S. No:	Species			4																	
1	Rhizophora apiculata	4	2	10	6	14	10	4	6					4	2	1	6				
2	Rhizophora mucronata	20	21		12																
3	Ceriops tagal									6								2			2
4	Lumnitzera racemosa																				
5	Phoenix paludosa									10	11	5	5					10	4	2	3
6	Excoecaria agallocha			6								2							4		1
7	Avicennia officinalis													42	22	26	10				
8	Avicennia marina			5										19	20	16	5				
9	Sonneratia alba		4		2																
10	Bruguiera gymnorhiza									6		2									
11	Heritiera littoralis										2	1									
				25																	
	Total	24	27		20	14	10	4	6	22	13	10	5	65	44	43	21	12	8	2	6

Index for Height Classes in Cms: A=0-30; B=31-60; C=61-90; D=91-120.

Blank space against a particular species indicates its absence in particular height class

Figure-3.7 Overall natural regeneration pattern in Mangroves of Long Island Forest Range



3.3.3. ESTIMATION OF AREA UNDER MANGROVES

Results obtained by first methodology i.e. by using Toposheets, coupled with ground truthing are shown in Table-3.18. This table shows the place-wise area under mangroves. Forest range wise mangrove area has been shown in Table-3.19.

Figures 3.8 to 3.12 are the maps prepared on the basis of study showing the mangrove area in different forest ranges. Original maps were prepared on the scale 1:50,000. Maps enclosed in the thesis are xerox copies of the original maps reduced in size.

The following results were obtained using second method i.e. Remote Sensing Map for calculation of Mangrove Area.

Total 1470 dots of the dot grid matrix fall within the mangrove area on the forest type map prepared by the visual interpretation of the Satellite imagery (Figure-3.13). Therefore, area under mangroves is 1470 X 6.25 i.e. 9187.50 or say 9188 ha.

TABLE-3.18

RESULTS OBTAINED ON ESTIMATION OF AREA UNDER MANGROVES USING TOPOSHEET COUPLED WITH GROUND TRUTHING

S.N.	Particulars of Place	Areas (ha.)	Remarks
1.	Betapur Range	280	Betapur River-Mouth Patch
2.	Lewis Inlet Region	2607	Entire Patch near Lewis Inlet
3.	Flat Island	114	Mangrove area of complete Island
4.	Long Island	126	Mangrove areas of Long Island only
5.	Cone Island	42	Entire Mangrove area of this Island
6.	Porlob Island	420	Entire Mangrove area of this Island
7.	North Passage Island	30	Entire Mangrove area of this Island
8.	Leela Bay Region	1616	Mangrove area from opposite to Papita dera camp to Leela Bay
9.	Kadamtala Jetty Region	2067	Mangrove area including west coast of Kadamtala village, Uttra jetty area upto opposite to Papita dera in Homfry Strait
10.	Boroniyol Jig Patch	2471	Area from Broom Valley camp, Boroniyol Porlobjig No.9 and No.15 road side camp but excluding the area of Wooly passage
11.	Bakultala Range	860	Entire area of Shyamkund and near by creeks
12.	Guitar Island	03	
13.	Rangat Range	1524	Entire area of Vishnupur, Bharatpur, Yeratta, Goal Pahar, and Rangat Bay
14.	Area between Wooly's Passage and Yoljig excluding the area of Mangrove Vegetation of Bakultala and Rangat Ranges	846	
	Total	13006 ha.	

TABLE-3.19

FOREST RANGE WISE MANGROVE AREA

S.N.	Forest Range	Area in Hectares	Reference in Table-3.18
1.	Bajalungta	9721	S.N.2,3,8,9,10,&14
2.	Bakultala	860	S.N.11
3.	Rangat	1524	S.N.13
4.	Betapur	280	S.N.1
5.	Long Island	621	S.N.4,5,6,7,&12
	TOTAL	13006	

FIGURE- 3.8

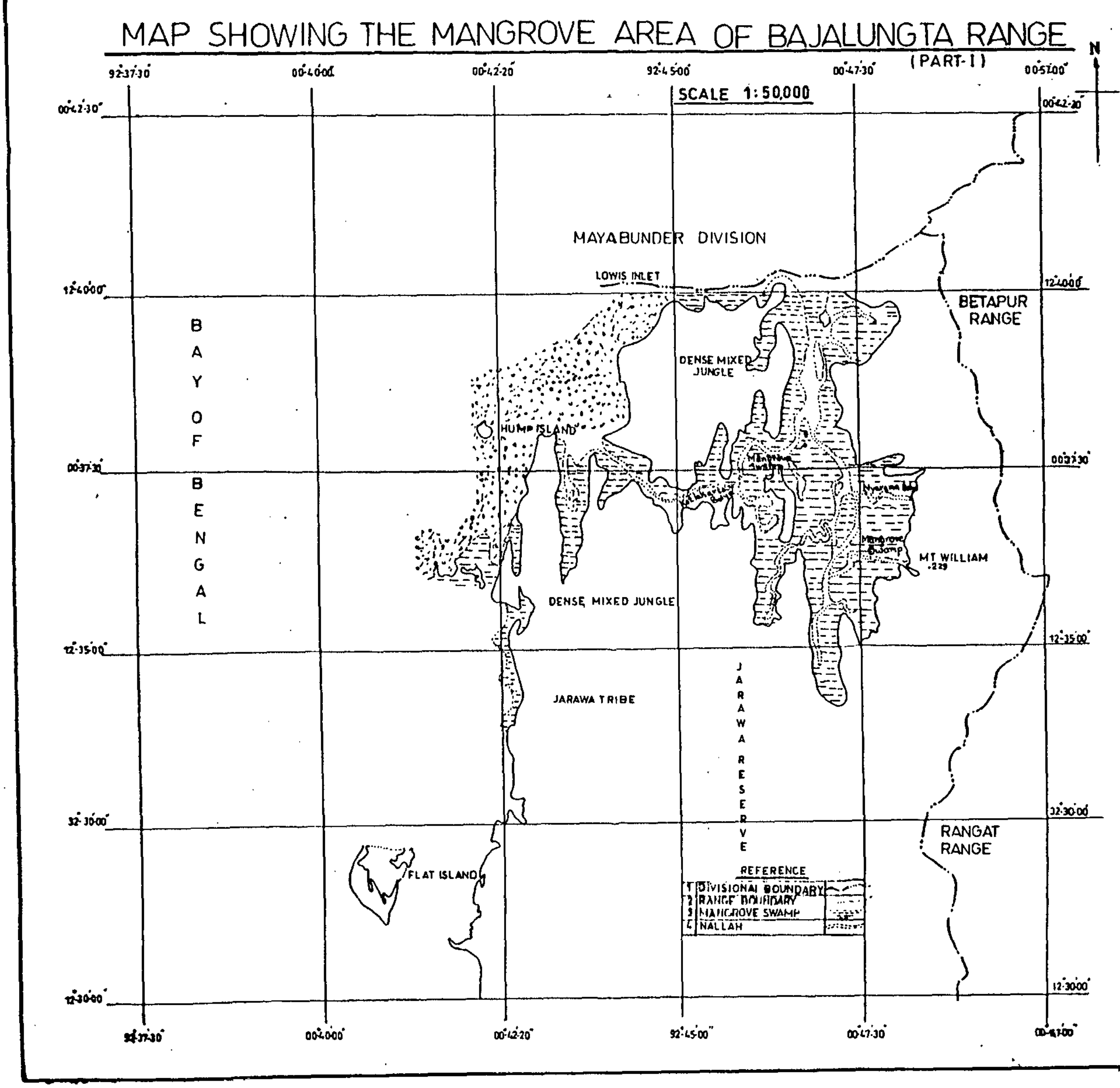

MAP SHOWING THE MANGROVE AREA OF BAJALUNGTA RANGE
(PART-I)
SCALE 1:50,000
N
MAYABUNDER DIVISION
LOWIS INLET
BETAPUR RANGE
B A Y O F B E N G A L
DENSE MIXED JUNGLE
HUMP ISLAND
MT WILLIAM
DENSE MIXED JUNGLE
JARAWA TRIBE
J A R A W A R E S E R V E
RANGAT RANGE
FLAT ISLAND
REFERENCE
1 DIVISIONAL BOUNDARY
2 RANGE BOUNDARY
3 MANGROVE SWAMP
4 NALLAH

FIGURE -3.9

MAP SHOWING THE MANGROVE AREA OF BAJALUNGTA RANGE (Part-II)

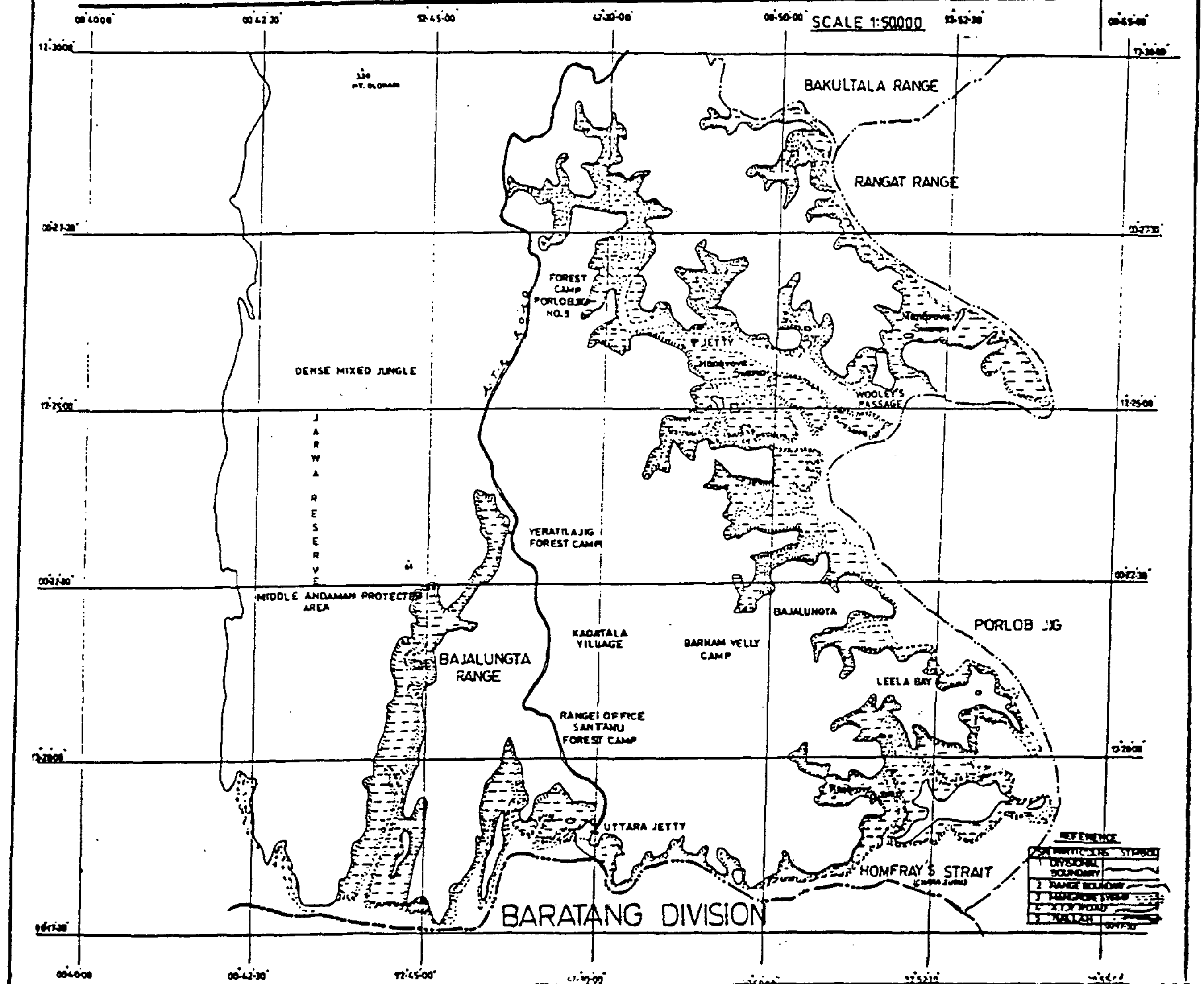


FIGURE -3.10

MAP SHOWING THE MANGROVE AREA OF RANGAT & BAKULTALA RANGE

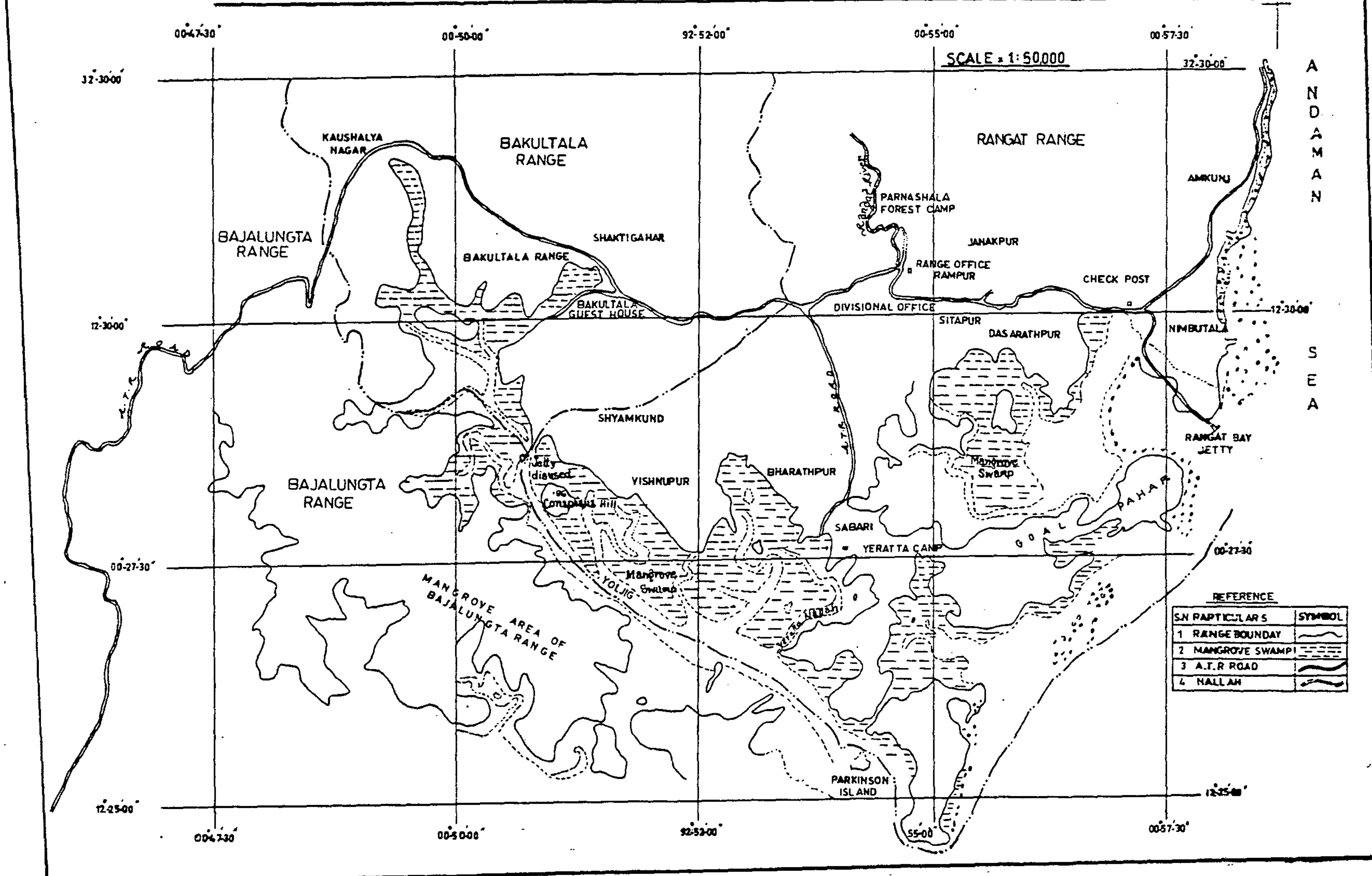


FIGURE -3.11

MAP SHOWING THE MANGROVE AREA OF BETAPUR RANGE

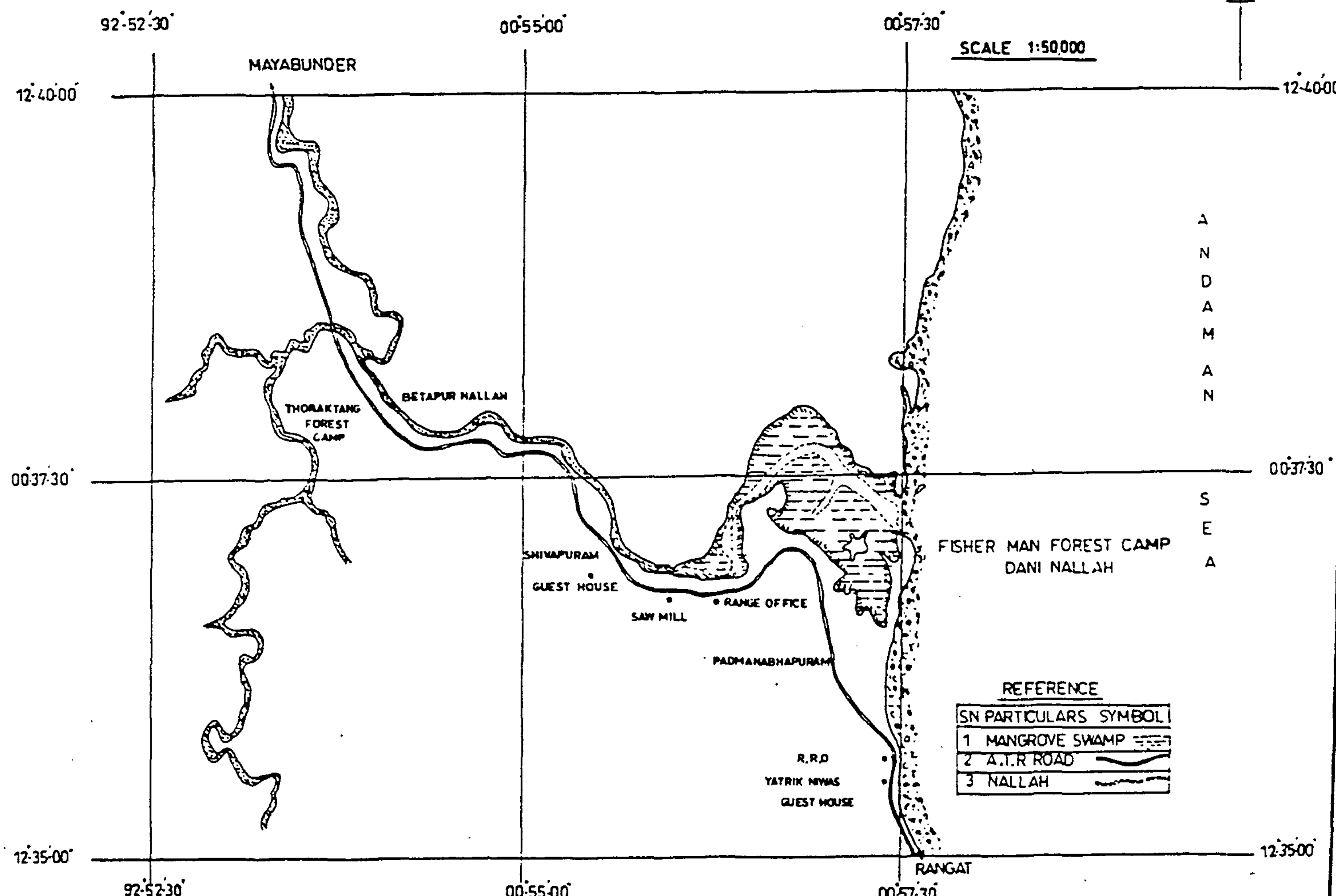
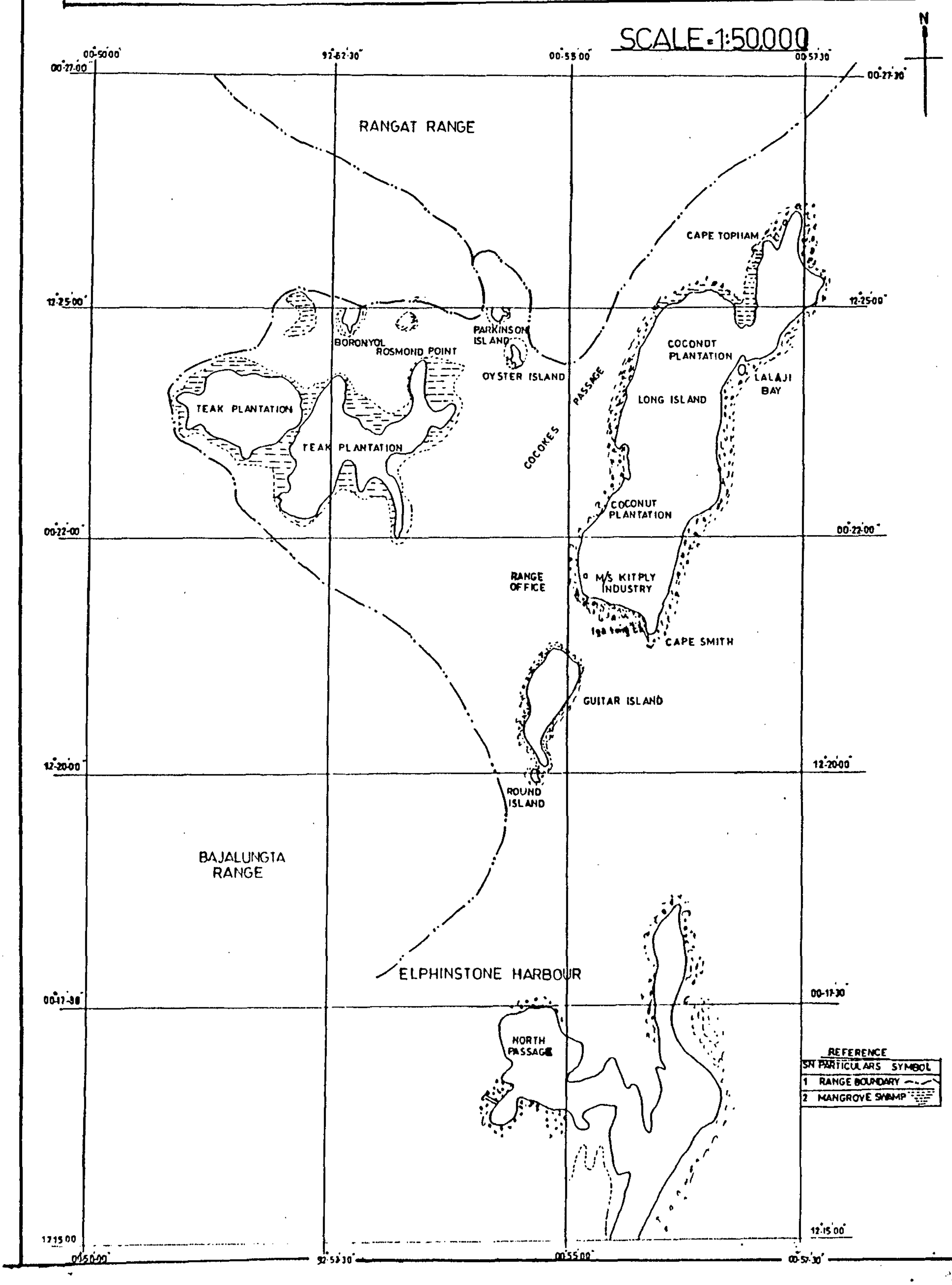


FIGURE- 3.12

MAP SHOWING THE MANGROVE AREA OF LONG ISLAND RANGE



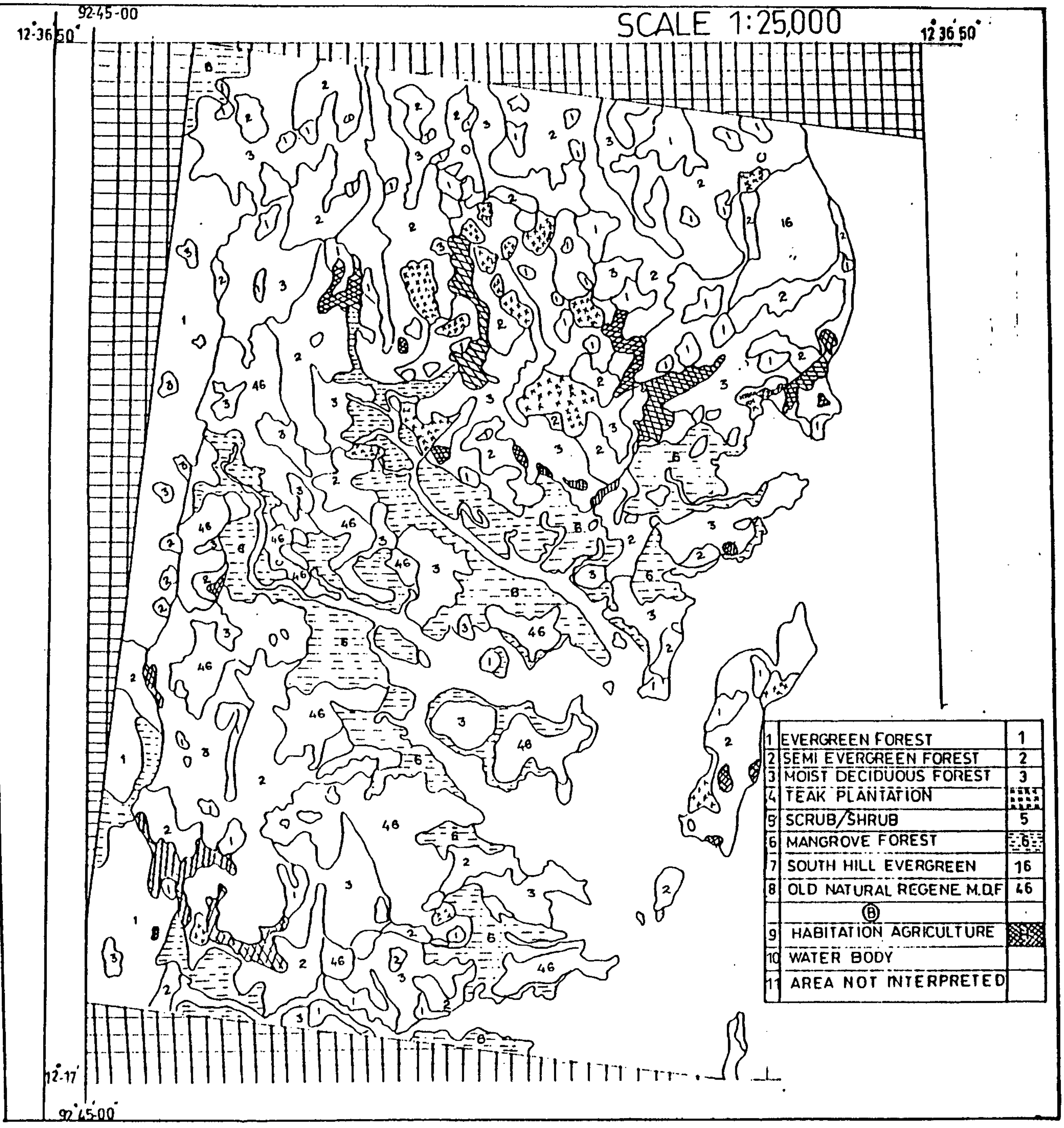


Figure- 3.13 Forest type map prepared by visual interpretation of SAR-X band diapositive of Middle Andaman

3.3.4. ESTIMATION OF EXPLOITABLE GROWING STOCK AND STAND STRUCTURE OF MANGROVES

Exploitable growing stock and stand structure of mangroves in five different Forest Ranges have been shown in Tables-3.20 to 3.24 while graphical representation of stand structure is shown in Figures 3.14 to 3.19. Results have been analyzed and discussed in the later part of this chapter.

TABLE-3.20

STAND STRUCTURE AND GROWING STOCK OF MANGROVES IN BAJALUNGTA FOREST RANGE

				Number of Stems in Various Girth Classes in Cms.									
S.No	Location of Sample Plot	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	>100	Growing Stock (Cu.M) >50 Cms g.b.h (ob)
1	Homfry St.	8	21	28	17	7	6	3	6	6	7	4	18.874
2	Homfry St.	11	12	3	14	18	7	7	7	7	5	3	19.919
3	Homfry St.	12	11	4	6	4	2	2	6	4	5	5	17.676
4	Homfry St.	14	36	19	11	15	5	7	3	5	8	3	20.547
5	Homfry St.	19	8	41	15	13	7		6	7	6	5	20.584
6	Homfry St.	20	8	23	24	11	5	6		8	6	4	19.325
7	Uttara Jetty	18	14	6	5	9	7	9	12	5	2	2	18.188
8	Uttara Jetty	18	33	20	13	12	10	7	3	2	3	1	12.757
9	Uttara Vill.	10	2	9	14	19	7	5	3	2	2	3	12.121
10	Uttara Vill.	12	21	60	16	8	4	9	4	4	2	1	11.745
	Total	142	166	213	135	116	60	55	50	50	46	31	171.736

Note: 1) All Sample Plots are of Uniform Size 250 X 4 Mts (0.1 Ha).
2) A Blank space in a rectangle represents the digit Zero.

Figure-3.14 Stand structure of mangroves in Bajalungta Forest Range

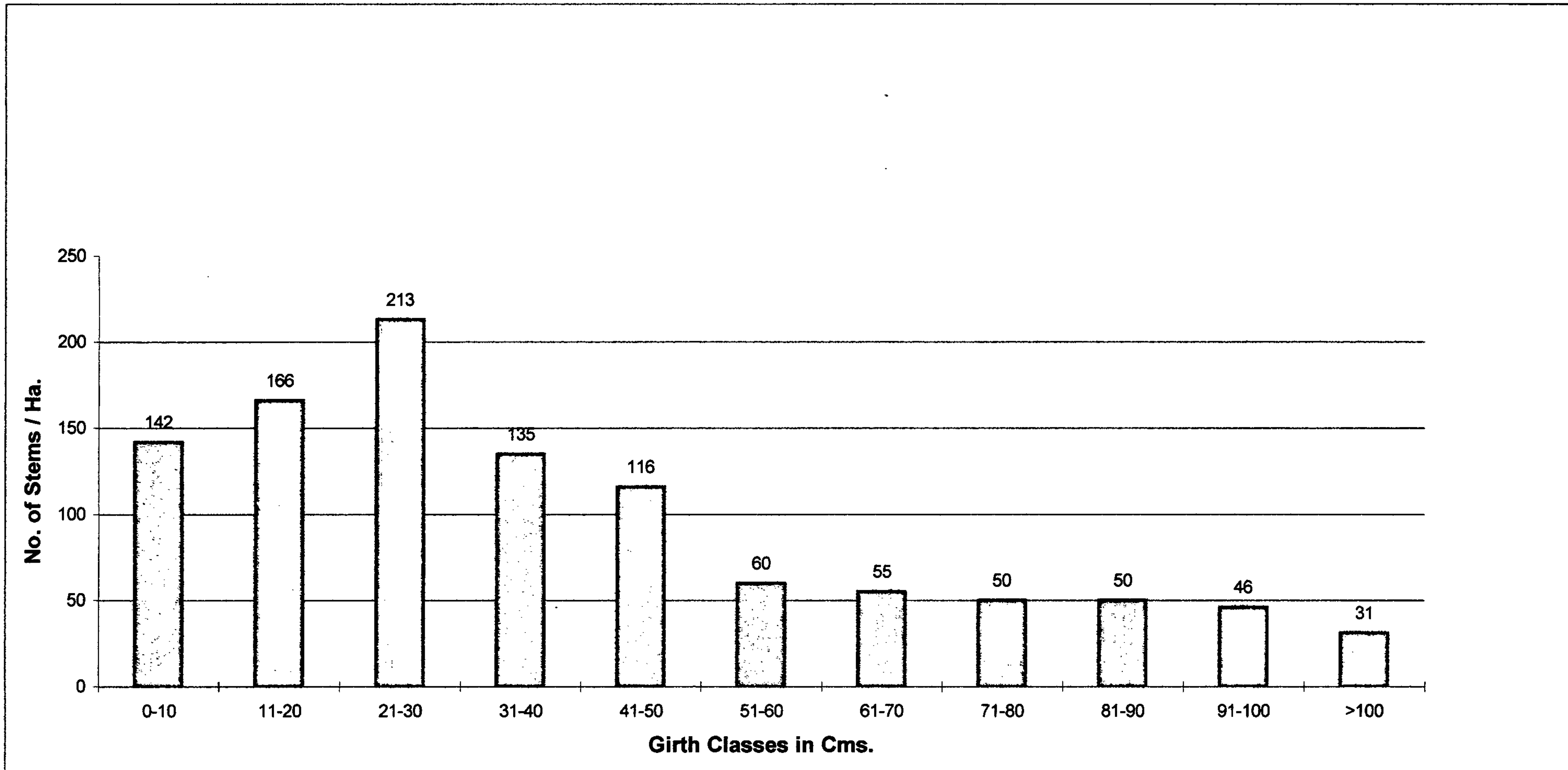


TABLE-3.21

STAND STRUCTURE AND GROWING STOCK OF MANGROVES IN BAKULTALA FOREST RANGE

				Number of Stems in Various Girth Classes in Cms.									
S.No	Location of Sample Plot	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	>100	Growing Stock (Cu.M) >50 Cms g.b.h (ob)
1	Shyamkund	2	25	16	15	18	13	8	7	10	9	5	38.621
2	Shyamkund	1	5	4	5	12	8	12	13	15	10	7	36.508
3	Shyamkund	3	6	8	8	15	3	5	6	1	3	6	15.533
4	Shyamkund		4	2	2	5	5	1		3	3	9	13.516
5	Shyamkund	15	42	54	17	3	1	1		1	3	2	5.3
6	Shyamkund	1	11	5	7	8	2	4	8	3	1	8	13.449
7	Bakultala	4	8	12	17	3	7	3	1	2	4	14	27.41
8	Bakultala		7	2	6	6	3	3		3	3	11	19.489
9	Bakultala	3	22	17	12	8	6	9	2	3	2	4	10.556
10	Kaushalya Nagar	1	22	23	14	8	4	8	4	2	2	4	10.661
	Total	30	152	143	103	86	53	54	41	43	40	70	191.043

Note: 1) All Sample Plots are of Uniform Size 250 X 4 Mts (0.1 Ha).
2) A Blank space in a rectangle represents the digit Zero.

Figure-3.15 Stand structure of mangroves in Bakultala Forest Range

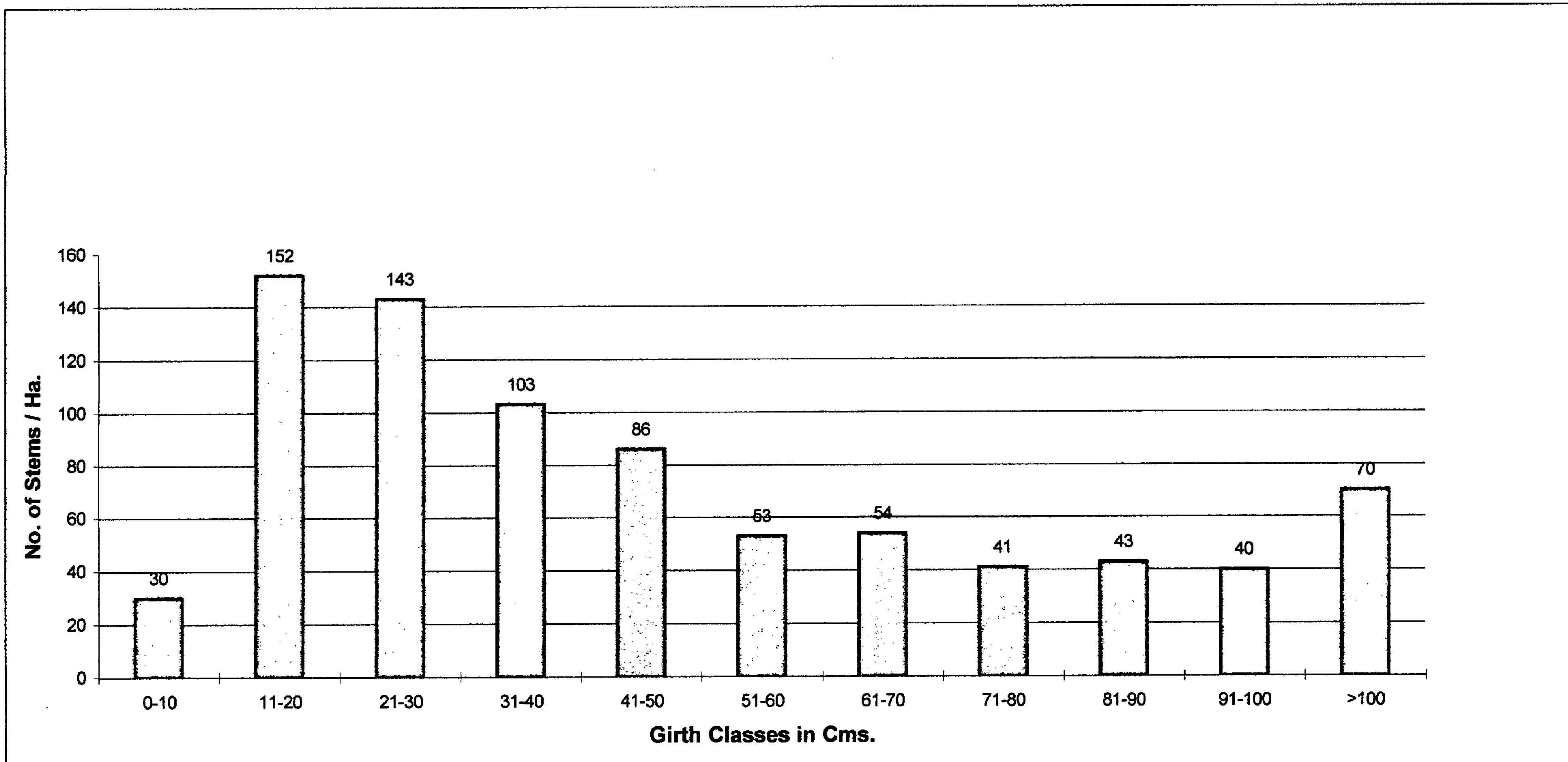


TABLE-3.22

STAND STRUCTURE AND GROWING STOCK OF MANGROVES IN RANGAT FOREST RANGE

				Number of Stems in Various Girth Classes in Cms.									
S.No	Location of Sample Plot	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	>100	Growing Stock (Cu.M) >50 Cms g.b.h (ob)
1	Yeratta Jetty	1	57	71	72	51	15	7	6	4	1	5	11.595
2	Yoljig Creek		7	6	6	5	6	9	3	10	5	18	25.406
3	Udislie Creek	4	9	9	5	2	4	5	5	8	9	20	29.772
4	Gol Tikry	17	56	58	55	35	28	7	7	1	3	1	9.182
5	Yeratta	11	55	18	17	48	43	3	13	4		1	22.103
6	Bharthpur	2	17	18	25	16	8	12	7	1	7	28	48.784
7	Golpahar	194	33	45	13	11	9	6	7	6	4	1	11.076
8	Goalpahar	131	58	46	35	27	19	10	2	3	3		7.851
9	Goalpahar	97	94	60	40	25	22	9	5	7	1	2	10.526
10	Nimbutala	20	46	60	42	31	20	17	8	2	2	1	8.927
	Total	477	432	391	310	251	174	85	63	46	35	77	185.222

Note: 1) All Sample Plots are of Uniform Size 250 X 4 Mts (0.1 Ha).

2) A Blank space in a rectangle represents the digit Zero.

Figure-3.16 Stand structure of mangroves in Rangat Forest Range

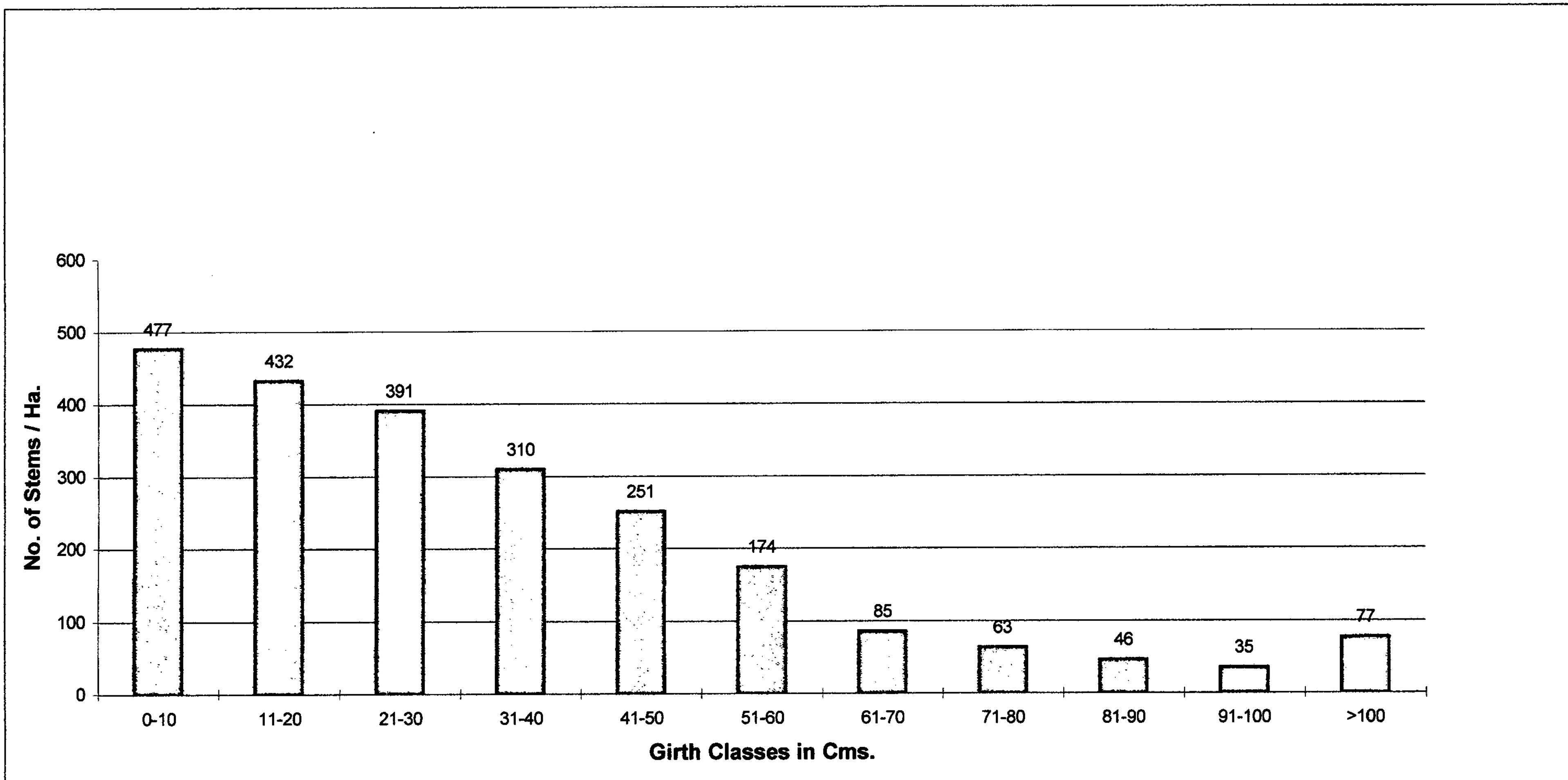


TABLE-3.23

STAND STRUCTURE AND GROWING STOCK OF MANGROVES IN BETAPUR FOREST RANGE

				Number of Stems in Various Girth Classes in Cms.									
S.No	Location of Sample Plot	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	>100	Growing Stock (Cu.M) >50 Cms g.b.h (ob)
1	Dhaninallah	416	72	12						1	2	1	3.187
2	Dhaninallah	195	27	6	3		1		3				2.349
3	Dhaninallah	209	16	9	3					1		3	4.399
4	Dhaninallah	73	1					1	1			1	1.691
5	Dhaninallah	76									1	10	12.498
6	Dhaninallah	51	1						1	1		4	6.645
7	Dhaninallah	36			1		1	2	2		2		5.333
8	Dhaninallah	118	39	9	2		2					1	2.204
9	Dhaninallah	73											
10	Dhaninallah	63	2	3					1				0.486
	Total	1310	158	39	9		4	3	8	3	5	20	38.796

Note: 1) All Sample Plots are of Uniform Size 250 X 4 Mts (0.1 Ha).

2) A Blank space in a rectangle represents the digit Zero.

Figure-3.17 Stand structure of mangroves in Betapur Forest Range

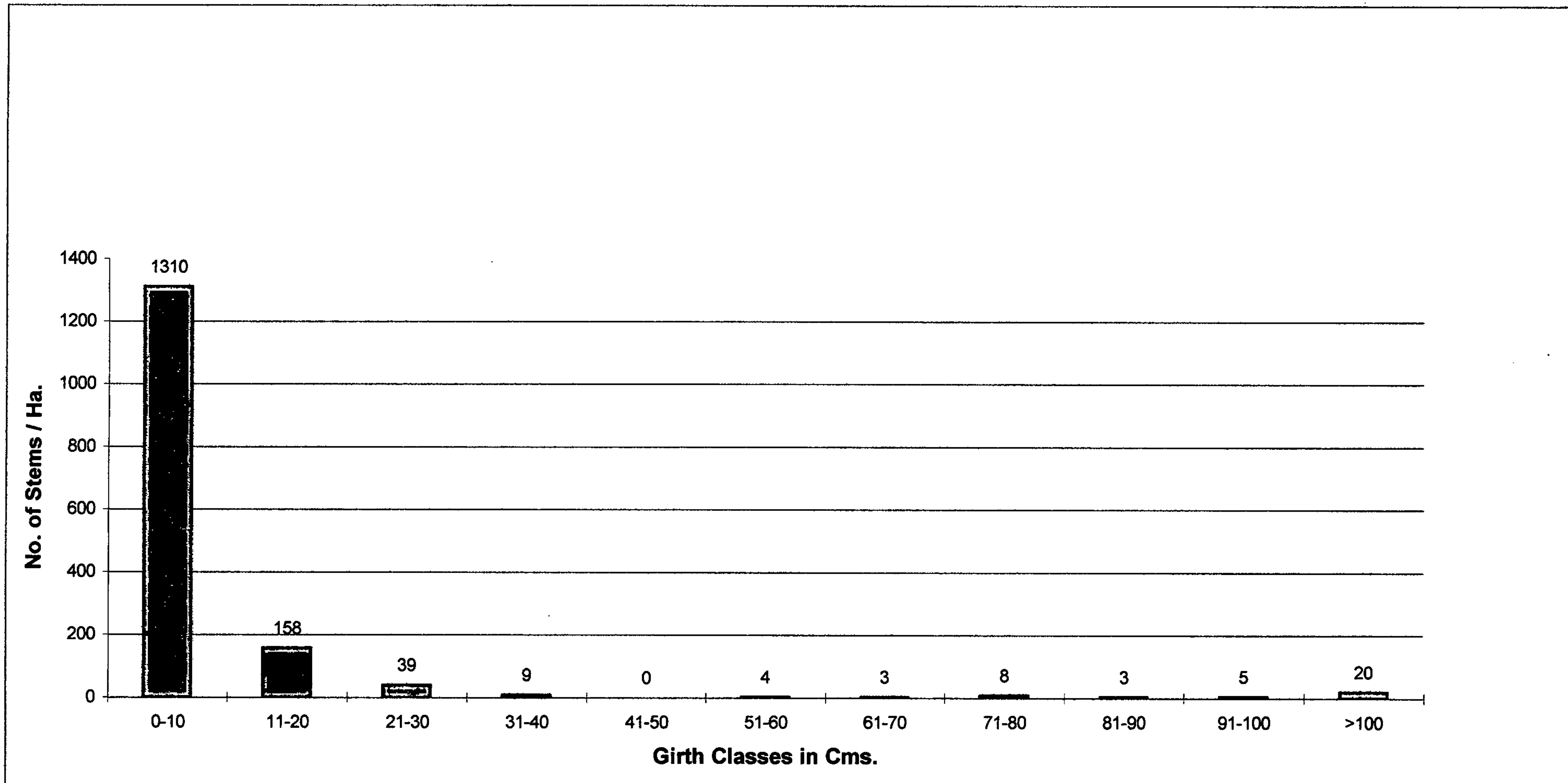


TABLE-3.24

STAND STRUCTURE AND GROWING STOCK OF MANGROVES IN LONG ISLAND FOREST RANGE

				Number of Stems in Various Girth Classes in Cms.									
S.No	Location of Sample Plot	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	>100	Growing Stock (Cu.M) >50 Cms g.b.h (ob)
1	Porlob Island	22	37	57	40	51	10	6	5	4		4	9.565
2	Porlob Island	51	48	30	30	17	18	11	3	2	2		7.081
3	Porlob Island	20	45	46	36	21	15	15	8	2	1	1	7.928
4	Porlob Island	36	52	26	29	10	10	12	4	2	2		6.5
5	Porlob Island	12	17	18	28	15	12	8	6				8.67
6	Porlob Island	40	42	19	20	11	10	14	6			2	7.575
7	North Passage Is.	27	26	16	9	6	11	10		3	1	2	6.928
8	North Passage Is.	36	16	10	12	8	6	12	4	1	2	1	7.676
9	Long Island	20	11	9		2	2	1		2		1	2.172
10	Long Island	12	8	7		2	1		1		2		1.46
	Total	276	302	238	204	143	95	89	37	16	10	11	65.555

Note: 1) All Sample Plots are of Uniform Size 250 X 4 Mts (0.1 Ha).
2) A Blank space in a rectangle represents the digit Zero.

Figure-3.18 Stand structure of mangroves in Long Island Forest Range

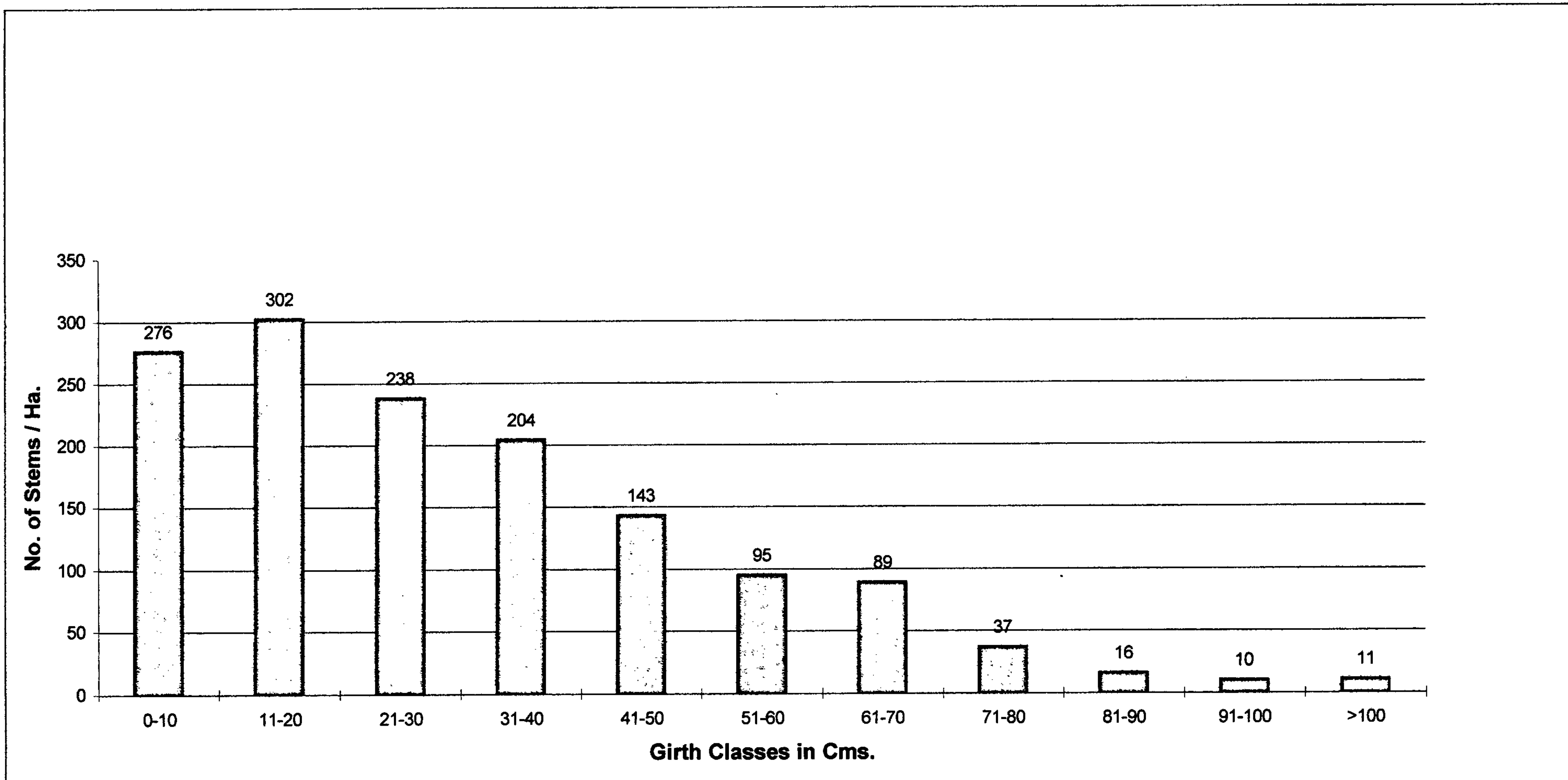
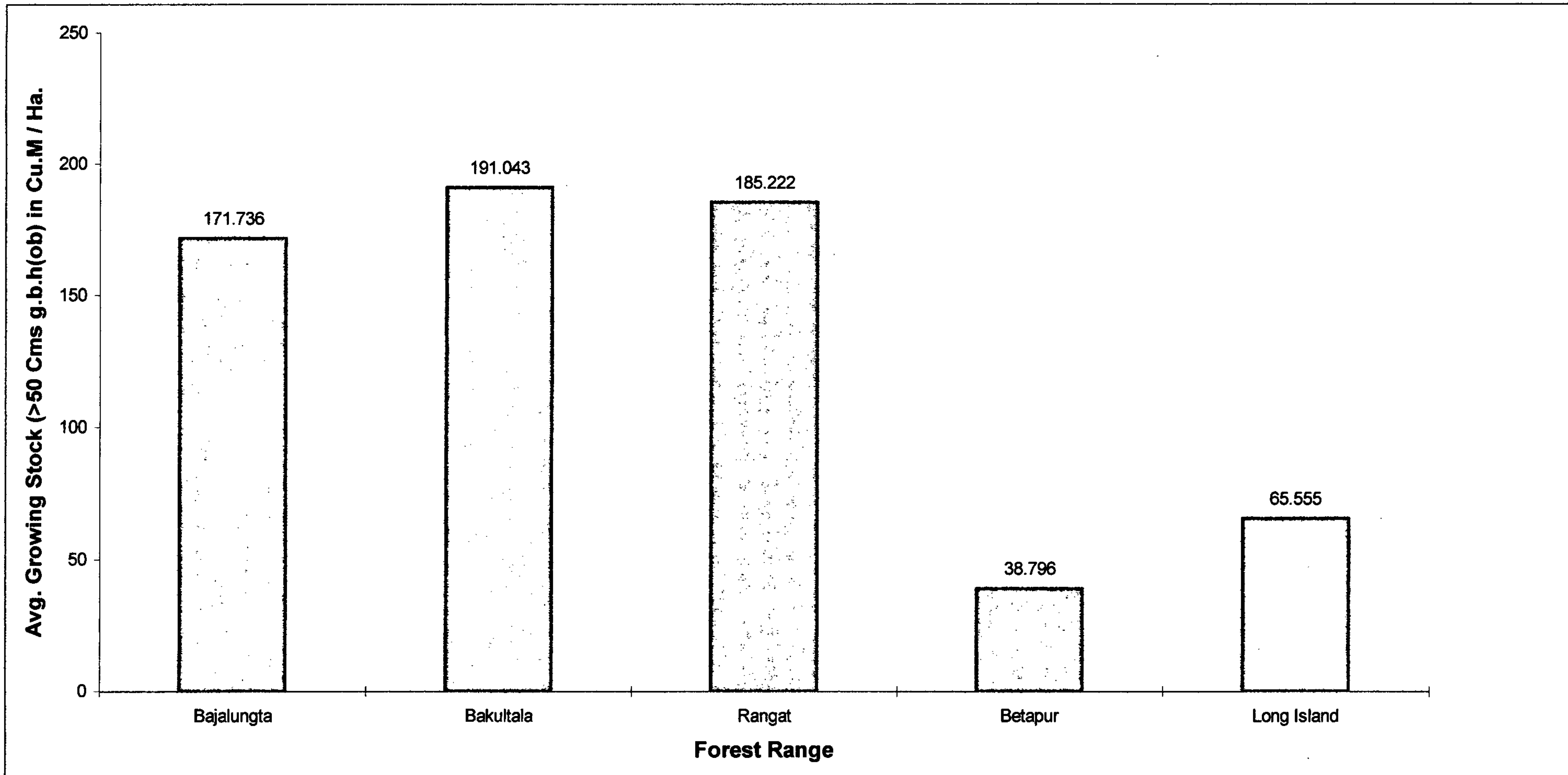


Figure-3.19 Average growing stock of mangroves in different ranges of Middle Andaman Forest Division



3.4. DISCUSSION

3.4.1. DISTRIBUTION AND ZONATION OF MANGROVES

The mangrove flora of Andaman and Nicobar Islands have been studied by Chengappa (1944), Banerji (1954, 1958), Sahani (1957) and Mall *et al.*, (1985) and Vasudeva Rao (1986). Mall *et al.*, (1985) have listed 26 exclusive mangrove species and 10 non-exclusive mangrove species. But perusal of literature including the work of Vasudeva Rao (1986); consultation with Botanical Survey of India, Port Blair Circle and personal observations in different mangrove areas of these islands reveal presence of 37 species of mangroves and their associated vegetation. The mangrove forests of Andaman and Nicobar are of the gregarious type i.e. they are wholly or largely composed of single species or a few closely allied one. This is a striking contrast to the ordinary type of tropical forests, which are composed of a large number of different families of trees and shrubs. These forests are, therefore, unique among tropical forests (Sahni, 1957; Krishnamurthy, 1985).

Mangroves colonize on different type of substrata, which include silty and clayey muds, calcareous muds, quartz sand, calcareous sand or mixtures of these (Anonymous, 1995). During the course of study, mangroves were seen growing in the areas having rocky substratum. They grow in the cracks on rocky substratum. Few such areas are Raman Bagicha, Ullapara, Guitar Island, and Lalaji Bay (Long Island) under the territorial jurisdiction of Middle Andaman Forest Division. Main mangrove species growing in the rocky areas were *Rhizophora apiculata, R. mucronata*, and *Sonneratia alba*. As the rocky substratum were not very favourable site for the mangrove growth, only small patches with limited number of trees were seen in these areas. Moreover, some dead and dying mangrove trees were also noticed in these areas.

Mangroves prefer sediments that are brought by the rainwater or transported and deposited by tidal currents. Mangrove formations on large flat areas along the creeks of Andamans were reported by Singh *et al.*, (1986).

Rhizophora apiculata, R. mucronata, Bruguiera gymnorrhiza, Heritiera littoralis, Sonneratia caseolaris, Nypa fruticans and *Excoecaria agallocha* are the prominent mangroves throughout the Bay Islands (Dagar *et al.*, 1991).

Xylocarpus mekongensis is the only species of the genus *Xylocarpus* having pneumatophores and was very rarely seen. After traversing mangrove areas of Middle Andaman extensively and intensively only two trees of this species could be located. One tree of *X. mekongensis* was noticed at Shyamkund and another very old and huge tree was noticed in the interior areas of mangrove swamps at Yerrata and its pneumatophores were seen within a circular area, around the tree, having radius of 6.6 meters. Natural regeneration of the species was conspicuously absent in the areas close to these mother trees. During the fruiting season of the year 1999, the *X. mekongensis* tree at Shyamkund produced 211 numbers of orange sized fruits but not even a single plant could grow naturally out of these fruits. In these areas, large numbers of crabs were noticed who ate the interior soft portion of the seeds.

Rhizophora apiculata, Bruguiera gymnorrhiza and *Ceriops tagal* are the dominant mangrove species in Middle Andaman (Table-3.25) but these species are rare in Goa. Many mangrove species like *Phoenix paludosa, Lumnitzera littorea, L. racemosa, Xylocarpus* species are found in Middle Andaman but absent from Goa.

The important tidal creeks which harbour mangroves in Andaman and Nicobar Islands are the Austin strait, Mayabunder, Monanpura, Kalighat, Parangara and Laxmipur in North Andaman; Porlobjig, Bimlungata, Charlungta, Homfry Strait, Lakralungta Yoljig and North Passage in the Middle Andaman; Havelock, Wrafter's creek, Baratang, Alexandra, Wandoor, Bambooflat, Burmanala, Chiriatapu, Pongibalu, Manjeri, Sipighat, Wright Myo to Shoal Bay, Ritchie's Archipelago, etc. in the South Andaman; Dugong creek of Little Andaman; Car Nicobar; Katchal Island; Nancowry Island and at the mouths of Galathea, Dugma, and Alexandra rivers and tidal creeks of Great Nicobar (Dagar and Singh, 1999).

Mangroves grow to a maximum size, density and species diversity in Malaysia, Indonesia, Andaman-Nicobar Islands and Papua New Guinea (Blasco, 1984). Mangroves of Andaman and Nicobar Islands have been reported by Singh *et al.,* (1986) to be richer and healthier in comparison to mangroves of Costa-Rica and Puerto- Rico (West Indies). Mangroves of Andaman and Nicobar have a special significance in the sense that they are the connecting link between SE, SW Asian mangroves and Indian Ocean mangroves. *Nypa* and *Heritiera* species are found in Andaman-Nicobar and in regions east of these islands but in the regions located on the west of these islands, these two mangrove species are not found.

Species of *Avicennia* form prominent associations in the Andaman group of islands and not in the Nicobars. *Lumnitzera littorea* is a prominent mangrove in the Andamans and also reported to occur in Tamil Nadu but not found elsewhere in India including the Nicobar Islands. *Nypa fruticans*, a useful mangrove palm, is more frequent in the Nicobars and creeks of South Andaman. *Phoenix paludosa* is found in Andamans but absent from Nicobars. *Ceriops decandra* is a rare species but *C. tagal* is common in Andamans. *Rhizophora stylosa*, which is found in Andamans but not found in other parts of India. *R. lamarckii* is very rare, found in Ritchie's Archipelao (South Andaman), and has not been reported from the Indian mainland. *Aegiceras corniculatum* shows a very restricted distribution in the Andamans. Though *Aegialitis rotundifolia*, *Kandelia candel*, and *Sonneratia griffithii* have been reported to occur but their distribution in Andaman and Nicobar Islands is doubtful (Dagar and Singh, 1999).

Present study showed distinct zonation in mangroves of Middle Andaman (Table-3.12). The species, which were noticed in the water front zone, were *Rhizophora apiculata, R. mucronata, Sonneratia alba, S. caseolaris, Xylocarpus granatum, X. Moluecensis, Avicennia officinalis* and *A. marina.* The species noticed in the middle zone were *Rhizophora apiculata, R. mucronata, Sonneratia caseolaris, Bruguiera gymnorrhiza, Ceriops tagal, Lumnitzera littorea* and *L. racemosa.* Towards the landward zone, *Xylocarpus granatum, X. moluecensis, Avicennia* *officinalis, A. marina, Excoecaria agallocha, Acrostichum aureum, Nypa fruticans, Phoenix paludosa, Heritiera littoralis, Aegiceras corniculatum* and *Acanthus ilicifolius* were noticed. Mall *et al.*, (1982) also identified three conspicuous zones in mangroves of Andaman and Nicobar Islands and named them as Proximal, Middle and Distal zones. Singh *et al.*, (1986) reported that mangrove community in Middle Andaman was greatly dominated by the family *Rhizophoraceae* and the seaward line was always occupied by *Rhizophora* species.

According to Balachandra (1988) mangrove vegetation of Andaman shows a distinct zonation pattern according to the degree of influence of tide, salinity, nature of soil, water table and drainage. He further reported as follows: "On coral reefs and exposed rocks *Rhizophora apiculata, R. mucronata* and *R. stylosa* grow as pioneer and exhibit stunted growth because of lack of soil and soil nutrients. Mangrove vegetation along the coastal line is the association of *Rhizophora* spp., *Bruguiera* spp., and *Sonneratia* spp. Soil of this zone is inundated by seawater twice in a day. Behind this association of *Rhizophora*, the soil level increases due to deposition of sand and pieces of broken corals by the wave action and the tidal water reaches this level during the spring tides, and this area is colonized by *Excoecaria agallocha, Lumnitzera racemosa, L. littorea* and others. The last association bordering the forest is of *Heritiera littoralis*".

Many types of mangrove associations were noticed during the course of study. *Rhizophora apiculata* and *R. mucronata* association was common towards water front side such as at Yerrata in Middle Andaman. *Rhizophora- Bruguiera* association were conspicuously seen at Yerrata, Shyamkund and many other places in Middle Andaman. *Bruguiera- Ceriops- Rhizophora* association could be seen at Yerrata, Dhaninallah and some other places in Middle Andaman. *Avicennia officinalis- A. marina* association was seen at Nimbutala, Kaushalyanagar, Betapur and many other places in Middle Andaman. *Rhizophora- Avicennia* association could be seen at Shyamkund. *Lumnitzera- Rhizophora, Lumnitzera- Ceriops*, and *Lumnitzera- Avicennia* associations was seen at Uttara along Homfry Strait. *Nypa fruticans- Xylocarpus granatum* association could be conspicuously seen in mangrove areas of Betapur Forest Range. Singh *et al.*, (1986) reported that each mangrove species usually occupied a salinity zone to which it was best adopted and identified seven major types of mangroves communities viz. *Rhizophora mucronata- R. apiculata, Bruguiera gymnorrhiza- Ceriops tagal, R. mucronata- B. gymnorrhiza, Lumnitzera littorea- Avicennia officinalis, B. gymnorrhiza-A. officinalis, Heritiera littoralis- Pongamia pinnata and Acanthus ilicifolius- Acrostichum aureum.*

Out of 60 number of mangrove species occurring all over the world, Asia is the richest region in species diversity with 44 number of species. Oceania with 39 number of species ranks second in species diversity. In other regions of the world species diversity is poor (Table- 3.26). Moreover, Asia has largest mangrove area (7,441,000 ha) followed by America (5,831,000 ha) and Africa (3,258,000 ha) (Saenger *et al.*, 1983). In India, Sunderbans (West Bengal) has the largest mangrove area followed by Andaman and Nicobar Islands which has second largest area under mangroves in India but Andaman and Nicobar Islands are richest in mangrove species diversity with 35 number of species (Table- 3.27).

The mangrove vegetation of Andaman and Nicobar Islands has close similarity with the Eastern zone mangroves of Bangladesh, Burma, Malaya, Thailand and Australia, in its floristic composition (Balachandra, 1988). In all about 37 species comprise the major and significant part of the Indian mangrove flora. Of these, 31 species are found along the East Coast excluding Andaman and Nicobar Islands. There are about 22 mangrove species along the West Coast (Dagar and Singh, 1999). As far as mangrove distribution is concerned four species namely *Acanthus ebracteatus, Rhizophora lamarckii, R. stylosa* and *Scyphiphora hydrophyllacea* occur exclusively in Andaman and Nicobar Islands (Table- 3.27). Field investigations have revealed that different environmental factors, which maintain ecological process in the mangrove ecosystem, are responsible for the species distribution (Banerjee and Gosh, 1998). River discharge is the prime source of nutrition to the mangrove ecosystem as well as it serves balancing net evaporation loss from its surface. The seasonal fresh water run off, changing the gradation of river, water salinity, tidal amplitude and sediment load provide a positive effect for maximum concentration of mangrove species. Along the East Coast, the river Ganga has maximum annual discharge 971 km3/year, the river Mahanadi 87 km3/year and the river Godavari 84 km3/year. Similarly the sediment yield varies from 1130 tonnes/km2/year, 470 tonnes/km2/year and 310 tonnes/km2/year respectively (Milliman & Meade 1983). Probably these factors are helping to develop best habitat of the mangrove species diversity along the East Coast.

The mangals of the western coast mostly form fringing vegetation along different parts of the coast-line where favourable conditions prevail. Only in certain estuarine parts of Goa, Maharashtra and Gujarat dense formation are seen although not varied in species diversity as in the east coast mangrove formations (Banerjee *et al.*, 1989).

The Andamans and Nicobar Islands harbour some of the best-developed mangrove vegetation and are less disturbed due to inaccessibility and remoteness compared to the mainland mangroves. An estimated 1190 sq kms area is covered with mangrove forests dispersed in several area of these islands (Anon., 1987). About 20 species predominate the mangroves. Well grown trees and shrubs of *Rhizophora mucronata, R. apiculata, Ceriops tagal, Bruguiera gymnorrhiza, B. parviflora, Xylocarpus granatum, Sonneratia alba, S. caseolaris, Aegiceras corniculatum, Avicennia officinalis, Cerbera manghas, Brownlowia tersa, Lumnitzera racemosa, Excoecaria agallocha, Acanthus ilicifolius, Heritiera littoralis* (more common along sea shores than in mangrove swamps) make a close canopied impenetrable forests. *Nypa fruticans* and *Phoenix paludosa* form impressive colonies along tidal creeks. *Acanthus volubilis* is rather uncommon (Banerjee, *et al.*, 1989).

Unlike in the mangroves of east coast estuarine areas where the species present a more or less uniform and characteristic zonation, the mangroves in these islands present no similarities and the zonation gets altered in different areas due to ecological conditions (Banerjee, *et al.*, 1989). Within the Andaman and Nicobar Islands, species diversity vary from region to region. Maximum 35 numbers of species have been reported from South Andaman followed by 30 number of species from Middle Andaman. Nicobar group of Islands has much less species as compared to the Andaman group of Islands (Dagar, *et al.*, 1991) (Table- 3.28).

As far as mangroves of Middle Andaman and Goa are concerned, there are differences in many ways. Middle Andaman has 30 mangrove species (Dagar, *et al.*, 1991) while Goa has only 16 mangrove species (Untawale, *et al.*, 1982). Middle Andaman has large number of mature to over mature trees of *Rhizophora* and *Bruguiera*, which can give sustainable yield of fuelwood and timber but mature and giant trees of these species are very rare in Goa. Large numbers of *Ceriops tagal* trees are available in Middle Andaman but in Goa only few plants of *C. tagal* can be seen. In general, mangroves of Middle Andaman are giants sized as compared to mangroves of Goa but there are few exceptions. Mature and overmature *Avicennia* trees are common in Goa especially along the Mandovi and Zuari estuaries but such mature and overmature trees of *Avicennia* trees are very rare in Middle Andaman. *Kandelia candel,* which is quite common in Goa at present is conspicuously absent from Middle Andaman. In fact, this species is extremely rare in Andaman and Nicobar group of Islands.

Mangroves species distribution with change in salinity is conspicuously depicted along various estuaries in Goa but such a conspicuous character is not seen so clearly in Middle Andaman. As the density of population is very low in these islands as compared to Goa, there are more biotic pressures on mangrove of Goa.

TABLE- 3.25

MANGROVE OCCURRENCE IN DIFFERENT FOREST RANGES OF MIDDLE ANDAMAN FOREST DIVISION

S.N.	Name of the Species	Bajalungta	Bakultala	Rangat	Betapur	L.Island
1.	*Rhizophora apiculata*	d	d	d	c	d
2.	*Rhizophora mucronata*	d	d	c	c	d
3.	*Bruguiera gymnorrhiza*	d	d	d	c	r
4.	*Ceriops tagal*	d	r	d	d	d
5.	*Avicennia officinalis*	d	c	r	r	d
6.	*Avicennia marina*	c	r	c	d	c
7.	*Excoecaria agallocha*	c	c	c	r	c
8.	*Acrostichum aureum*	d	c	c	r	r
9.	*Lumnitzera littorea*	d	r	r	r	d
10.	*Xylocarpus granatum*	c	c	c	r	r
11.	*Xylocarpus moluecensis*	c	c	c	-	-
12.	*Nypa fruticans*	c*	-	-	d	-
13.	*Phoenix paludosa*	d	c	d	c	d
14.	*Heritiera littoralis*	c	c	c	r	r
15.	*Aegiceras corniculatum*	c	r	r	-	-
16.	*Sonneratia alba*	r	r	r	-	r
17.	*Sonneratia caseolaris*	-	r	r	r	-
18.	*Acanthus ilicifolius*	r	r	r	r	r
19.	*Lumnitzera racemosa*	r	r	r	r	r

Index: d= Dominant; c= Common; r =Rare; - =Absent;

c*= common but locally dominant at Dhaninallah

TABLE- 3.26

WORLD WIDE DISTRIBUTION OF THE MANGROVES

S.N.	Species	Life Form	Distribution					
			I	II	III	IV	V	VI
1.	*Acanthus ebracteatus*	S	+	+				
2.	*Acanthus ilicifolius*	S	+	+				
3.	*Acanthus volubilis*	S	+					
4.	*Aegialitis annulata*	S		+				
5.	*Aegialitis rotundifolia*	S	+					
6.	*Aegiceras corniculatum*	S	+	+				
7.	*Avicennia alba*	T	+	+				
8.	*Avicennia bicolor*	T			+			
9.	*Avicennia eucalyptifolia*	T		+				
10.	*Avicennia germinanas*	T		+	+	+		
11.	*Avicennia intermedia*	T	+					
12.	*Avicennia lanata*	T	+					
13.	*Avicennia marina*	T	+	+				+
14.	*Avicennia officinalis*	T	+	+				
15.	*Avicennia rumphiana*	T		+				
16.	*Avicennia tomentosa*	T				+		
17.	*Avicennia tonduzii*	T			+			
18.	*Bruguiera cylindrica*	T	+	+				
19.	*Bruguiera exaristata*	T		+				
20.	*Bruguiera gymnorrhiza*	T	+	+				+
21.	*Bruguiera hainesii*	T	+	+				
22.	*Bruguiera parviflora*	T	+	+				
23.	*Bruguiera sexangula*	T	+	+				
24.	*Camptostemon philippinensis*	T	+					
25.	*Camptostemon schultzii*	T	+	+				
26.	*Ceriops decandra*	T	+	+				
27.	*Ceriops tagal*	T	+	+				+
28.	*Conocarpus erectus*	T				+	+	
29.	*Cynometra iripa*	T	+	+				
30.	*Cynometra ramiflora*	T	+					
31.	*Excoecaria agallocha*	T	+	+				
32.	*Heritiera fomes*	T	+					
33.	*Heritiera littoralis*	T	+	+				+
34.	*Kandelia candel*	T	+					
35.	*Laguncularia racemosa*	T			+	+	+	
36.	*Lumnitzera littorea*	S/T	+	+				
37.	*Lumnitzera racemosa*	S/T	+	+				+
38.	*Nypa fruticans*	P	+	+			+	

39.	*Osbornia octodonta*	S	+	+				
40.	*Pelliciera rhizophorae*	T			+			
41.	*Phoenix paludosa*	P	+					
42.	*Rhizophora apiculata*	T	+	+				
43.	*Rhizophora harrisonii*	T			+	+	+	
44.	*Rhizophora lamarckii*	T		+				
45.	*Rhizophora mangle*			+	+	+	+	
46.	*Rhizophora mucronata*	T	+	+				+
47.	Rhizophora racemosa	T				+	+	
48.	*Rhizophora x selala*	T		+				
49.	*Rhizophora stylosa*	T	+	+				
50.	*Scyphiphora hydrophyllacea*	S	+	+				
51.	*Sonneratia alba*	T	+	+				+
52.	*Sonneratia apetala*	T	+					
53.	*Sonneratia caseolaris*	T	+	+				
54.	*Sonneratia griffithii*	T	+					
55.	*Sonneratia ovata*	T	+	+				
56.	*Xylocarpus australasicus*	T	+	+				
57.	*Xylocarpus granatum*	T	+	+				+
58.	*Xylocarpus mekongensis*	T	+					
59.	*Xylocarpus moluccensis*	T	+	+				+
60.	*Xylocarpus parvifolius*	T	+					
TOTAL			**44**	**39**	**7**	**7**	**6**	**8**

INDEX

S= Shrub; T= Tree; P= Palm

+ = Presence of Species; Blank space in a block signifies absence of species

Digits I-VI indicate the geographical distribution of mangroves in

I-Asia; II- Oceania; III- West Coast of Americas; IV- East Coast of Americas; V- West Coast of Africa; VI- East Coast of Africa and the Middle East

SOURCE: Saenager *et al*., (1983)

TABLE- 3.27 DISTRIBUTION OF MANGROVES IN INDIA

S. N.	Species	West Coast						East Coast				
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI
1.	*Acanthus ebracteatus*											+
2.	*Acanthus ilicifolius*	+	+	+	+	+	+	+	+	+	+	+
3.	*Acanthus volubilis*							+				+
4.	*Aegialitis rotundifolia*	+	+	+	+	+		+		+		+
5.	*Aegiceras corniculatum*	+	+	+	+	+		+	+	+		+
6.	*Avicennia alba*	+	+	+	+			+	+	+	+	+
7.	*Avicennia marina*	+	+	+	+			+	+	+	+	+
8.	*Avicennia officinalis*	+	+			+		+	+	+	+	+
9.	*Bruguiera cylindrica*	+	+			+		+	+	+	+	+
10.	*Bruguiera gymnorrhiza*	+	+	+	+	+	+	+	+	+	+	+
11.	*Bruguiera parviflora*	+	+	+	+	+	+	+	+			+
12.	*Bruguiera sexangula*	+	+				+	+				+
13.	*Ceriops decandra*	+	+				+	+	+	+	+	+
14.	*Ceriops tagal*	+	+			+		+	+	+	+	+
15.	*Cynometra iripa*							+				+
16.	*Cynometra ramiflora*	+	+					+	+	+	+	+
17.	*Excoecaria agallocha*	+	+	+	+	+		+	+	+	+	+
18.	*Heritiera fomes*								+			
19.	*Heritiera kanikensis*								+			
20.	*Heritiera littoralis*							+				+
21.	*Kandelia candel*	+	+	+	+	+	+	+	+	+	+	+
22.	*Lumnitzera littorea*										+	+
23.	*Lumnitzera racemosa*		+				+	+	+	+	+	+
24.	*Nypa fruticans*							+	+			+
25.	*Phoenix paludosa*							+	+			+
26.	*Rhizophora apiculata*	+	+	+	+	+		+	+	+	+	+
27.	*Rhizophora lamarckii*											+
28.	*Rhizophora mucronata*	+	+	+	+	+	+	+	+	+	+	+
29.	*Rhizophora stylosa*											+
30.	*Scyphiphora hydrophyllacea*											+
31.	*Sonneratia alba*		+	+	+	+						+
32.	*Sonneratia apetala*		+	+	+			+	+	+	+	+
33.	*Sonneratia caseolaris*	+	+	+	+			+	+			+
34.	*Sonneratia griffithii*							+				+
35.	*Xylocarpus granatum*	+	+	+				+	+		+	+
36.	*Xylocarpus mekongensis*							+	+			+
37.	*Xylocarpus moluccensis*							+		+		+
	TOTAL	**19**	**22**	**15**	**14**	**13**	**8**	**29**	**24**	**19**	**17**	**35**

INDEX: States/ Union territories of I- Gujarat; II- Maharashtra; III- Goa; IV- Karnataka; V- Kerala; VI- Laccadive; VII- West Bengal; VIII- Orissa; IX- Andhra Pradesh; X- Tamil Nadu; XI- Andaman& Nicobar Islands

SOURCE: Dagar & Singh (1999)

TABLE- 3.28 DISTRIBUTION OF MANGROVES IN ANDAMAN AND NICOBAR ISLANDS

S.N.	Species	Distribution in Andaman & Nicobar						
		ANDAMAN				NICOBAR		
		N	M	S	L	N	C	S
1.	*Acanthus ebracteatus*	+	+	+				
2.	*Acanthus ilicifolius*	+	+	+				+
3.	*Acanthus volubilis*		+	+				+
4.	*Aegialitis rotundifolia*			+				
5.	*Aegiceras corniculatum*		+	+				
6.	*Avicennia alba*		+	+				
7.	*Avicennia marina*	+	+	+				
8.	*Avicennia officinalis*	+	+	+				
9.	*Bruguiera cylindrica*		+	+				
10.	*Bruguiera gymnorrhiza*	+	+	+	+	+	+	+
11.	*Bruguiera parviflora*	+	+	+	+	+		
12.	*Bruguiera sexangula*		+	+		+	+	+
13.	*Ceriops decandra*			+				
14.	*Ceriops tagal*	+	+	+	+	+		
15.	*Cynometra iripa*			+				
16.	*Cynometra ramiflora*		+	+		+		
17.	*Excoecaria agallocha*	+	+	+	+	+	+	+
18.	*Heritiera littoralis*	+	+	+	+	+	+	+
19.	*Kandelia candel*			+				
20.	*Lumnitzera littorea*	+	+	+				
21.	*Lumnitzera racemosa*	+	+	+				
22.	*Nypa fruticans*	+	+	+	+	+	+	+
23.	*Phoenix paludosa*		+	+				
24.	*Rhizophora apiculata*	+	+	+	+	+	+	+
25.	*Rhizophora lamarckii*		+	+			+	
26.	*Rhizophora mucronata*	+	+	+	+	+	+	+
27.	*Rhizophora stylosa*	+	+	+			+	
28.	*Scyphiphora hydrophyllacea*		+	+	+			
29.	*Sonneratia alba*		+	+				
30.	*Sonneratia apetala*		+	+				
31.	*Sonneratia caseolaris*	+	+	+	+	+	+	+
32.	*Sonneratia griffithii*			+				
33.	*Xylocarpus granatum*	+	+	+.	+	+	+	+
34.	*Xylocarpus mekongensis*		+	+				
35.	*Xylocarpus moluccensis*	+	+	+	+	+		
	TOTAL	**18**	**30**	**35**	**12**	**13**	**11**	**11**

Index: N-North; M- Middle; S-South; L-Little; C-Central
+ = Presence and blank block represent absence of the species

Source: Dagar (1991)

PLATE: 3.1

Natural regeneration in manmade degraded mangrove area at Shyamkund, Middle Andaman

PLATE: 3.2

Propagules in *Rhizophora mucronata* along Yerrata creek in Middle Andaman

3.4.2. NATURAL REGENERATION IN MANGROVES

Natural regeneration is preferred mainly due to the reason that it is economical. Seth & Mathauda, (1957) reported that for regenerating the forests, reliance was primarily placed on natural regeneration. Little work has been done so far to study the natural regeneration status of mangroves at different point of time in different localities. No such study was carried out earlier in Middle Andaman. During the course of present study, *Rhizophora apiculata*, most abundantly found species, was found to be showing good regeneration in all the ranges except in Betapur Range where it was moderate. Probable reason for this moderate regeneration was comparatively lesser number of mother trees of *Rhizophora apiculata* in Betapur Range. Although *Rhizophora mucronata* was also abundantly noticed in the Division but as compared to *R. apiculata* its occurrence was very less. If we compare area wise occurrence of these two species, the ratio may come around 10:1. *Rhizophora mucronata* showed good regeneration in Bajalungta, Bakultala, and Long Island Ranges but showed poor regeneration in Rangat and Betapur Ranges. Biotic interference was noticed as main factor for the poor natural regeneration. In Goa, on an overall basis, *R. mucronata* was showing good regeneration while regeneration of *R. apiculata* was not satisfactory.

Mathauda, (1957) observed that natural regeneration was usually adequate on sites suitable for growth of mangroves but it was, sometimes, hampered by biotic factors like heavy grazing by wild game and domestic cattle or excessive felling. Domestic cattle especially buffalo were serious offenders in the areas adjoining habitation. They browsed on young regeneration and new coppice shoots.

Damage by domestic cattle is especially high in the mangroves of the eastern coast of India. In the Godavari mangroves right-holders keep semi-wild buffaloes which stay inside the forest throughout the year. Puri & Jain, (1957) reported that the mangroves in the Western India did not form dense forests at any place due to intense biotic interference.

Natural regeneration in mangroves of Sundarbans of Bangladesh is inadequate due to human interactions and influences (Naskar & Mandal, 1999).

Shafi (1982) reported that the natural regeneration of mangroves of Bangladesh was decreased by 100% during 1981 in comparison to 1959-60. These were due to diversion of the Ganga River flow towards Bhagirathi through Farakka and consequent rise of the soil and water salinity and sufficient number of mother trees were also absent.

Plate- 3.1 shows an area at Shyamkund (Middle Andaman) where excessive tree felling degraded the area but after giving protection to the area against biotic interference, natural regeneration started coming up. Plate- 3.2 shows propagules of *Rhizophora mucronata* along Yerrata creek in Middle Andaman.

Bruguiera gymnorrhiza showed good renewal of crop in Bakultala range, while poor renewal was noticed in Bajalungta and Long Island Ranges. *B. gymnorrhiza* was showing poor regeneration in Goa. *Acrostichum aureum* was noticed in some clear felled *Bruguiera* patches. Seth & Mathauda, (1957) reported that in the driest areas carrying *Bruguiera gymnorrhiza* clear felling was usually followed by the dense growth of *Acrostichum* fern, that marked the end of mangrove forest. Size of *Bruguiera gymnorrhiza* propagule is much smaller as compared to that of *Rhizophora* and its lower end is also not so pointed as in the case of *Rhizophora*. Therefore, species with smaller propagules and less pointed end are likely to have low rate of striking the ground for successful embedding and germination. Vast majority of mangrove species are strong light demanders. Important exceptions are *Bruguiera gymnorrhiza* and *B. parviflora* (Seth & Mathauda, 1957).

There are big patches of intertidal vacant land in Middle Andaman at Kaushalyanagar, Shyamkund, Yerrata, Nimbutala and Betapur where no regeneration was coming up as noticed during the present study. This may be due to clearing felling of mangroves in these areas in the past. Singh *et al.*, (1986) also reported similar observations from the Alexander Island and Wandoor (South Andaman), where felling in many places was so common that the whole areas became devoid of mangrove vegetation and there was no natural regeneration, which resulted in change of the basic structural pattern of mangrove forests

Ceriops tagal showed good regeneration in all the ranges except in Bakultala Range where the species did not occur naturally. Efforts were made for introduction of *Ceriops tagal* in this range by planting one thousand numbers of propagules but all the plants died within one year of planting. *Phoenix paludosa* showed good regeneration in all the five ranges of the division.

Avicennia officinalis was found to show good regeneration in Bajalungta, Bakultala and Long Island Ranges but at few places crabs were seen eating young leaves of seedlings (Personal observation). The *Avicennia marina* was showing good regeneration in all the ranges except Betapur Range where it was moderate. Cattle pressure in Betapur Range was adversely affecting the natural regeneration of this species. Plants with stunted growth were common due to continuous browsing by the cattle. In Goa, good and moderate regeneration was noticed in respect of *A. officinalis* and *A. marina.*

Excoecaria agallocha showed good regeneration in Bakultala Range, moderate regeneration in Bajalungta and Rangat Ranges and poor regeneration in Betapur and Long Island Ranges. *Acrostichum aureum* showed good regeneration in all the ranges except in Long Island Range. During the course of study, local people including tribals were seen collecting tender shoots of *Acrostichum* for making vegetable. *Acrostichum* fern may often inhibit natural regeneration of other mangrove species. In certain areas *Acrostichum* fern grows vigorously with the introduction of light (Seth & Mathauda, 1957). So far, *Acrostichum aureum* is neither a serious threat in Goa nor in Middle Andaman.

Lumnitzera littorea was observed to be growing in good quantity in all the ranges except Rangat and Betapur Ranges. Insufficient number of mother plants seemed to be the cause of poor regeneration. Natural regeneration of *Xylocarpus granatum* and *X. moluecensis* was poor in the whole division. Illegal collection of large quantity of fruits and attack of insects on the fallen seeds seemed to be the prime cause of the poor regeneration. *Nypa fruticans* dominantly occurred in Betapur Range but its natural regeneration was poor as the people collected the young fruit bunches for eating kernels. The species also occurred in Bajalungta Range where its natural regeneration was good.

In the Sundarbans, chital and barking deer cause serious damage to regeneration of species like *Heritiera, Excoecaria agallocha* and *Nypa fruticans* and pigs are fond of uprooting seedlings (Mathauda, 1957). However, in Middle Andaman, no appreciable damage, caused by the wildlife, was noticed. Although, large number of chital, barking deer and wild boars were noticed in Middle Andaman.

Heritiera littoralis showed poor regeneration in all the ranges expect in Bakultala Range where it was comparatively good. In various localities large number of fallen seeds were seen attacked by the insects which might be the cause of poor regeneration of the species. *Aegiceras corniculatum* occurred significantly only in Bajalungta Range where its regeneration was good.

Mathauda, (1957) reported that the *Heritiera* and *Carapa moluccensis* seeds were destroyed in large quantities by *Hymenoptychis sordidia* and *Hypsipyla robrota* respectively in the Sundarbans. Insects also damage foliage and timber to some extent.

Mathauda (1957) observed absence of natural regeneration of mangroves on the newly developed land due to continuos process of accretion. Similar observations were noticed on a newly developed small island in Yoljig creek on the way to Long Island from Yerrata Jetty in Middle Andaman. Soil on this new island was under the process of stabilisation and little vegetation in the form of small grasses was noticed. In the same creek, there was another small but old island, which was full of mangroves. Rao, (1957) reported that the Sundarbans was in the process of extending north to south for many centuries and there was no island, which was not covered by natural vegetation confirm the view that natural regeneration was taking place all along.

The newly formed muddy flats are colonised by *Rhizophora* spp., in association with *Arthrocnemum* and *Salicornia.* Slopes are covered by *Avicennia* and *Acanthus ilicifolius*, although at places, *Aegialitis* becomes gregarious. The flats which are covered by fresh water during rains carry a luxuriant crop of *Oryza coarctata* (Khan, 1957).

Sonneratia alba was found to show moderate regeneration in Bajalungta, Long Island Ranges and poor regeneration in Rangat and Bakultala Ranges. The species did not occur significantly in Betapur Range. *Sonneratia caseolaris* showed moderate regeneration in Betapur Range and poor regeneration in Rangat and Bakultala Ranges. It was not significant in Bajalungta and Long Island Ranges from occurrence point of view. In Goa good natural regeneration of *Sonneratia alba* and *S. caseolaris* was noticed in many localities During the course of field visits in Middle Andaman, profuse budding in genus *Sonneratia* was seen but due to attack by some insect/ pest less than 1% of total buds bloom into flowers. This results in formation of only few fruits. Further, crabs were also noticed eating the fallen fruits. Seth & Mathauda, (1957) also reported that the natural regeneration was often inhibited by crabs. In certain areas, crabs caused widespread damage by girdling the young seedlings. No practicable control measures have been discovered against this type of injury.

Acanthus ilicifolius showed good regeneration in Bakultala Range. *Lumnitzera racemosa* showed good regeneration in Long Island Range and poor natural regeneration in Bakultala and Rangat Ranges. Protection of forests is very necessary to promote natural regeneration. Puri & Jain, (1957) reported that if marshy coasts of the country were protected, natural regeneration of mangroves would be rapid.

In Bajalungta Range (Figure-3.3), the natural regeneration pattern showed that once the seedlings crossed the height of 30 cms. there were almost cent percent chances of their establishment. Young seedlings were observed to be most vulnerable to the damage by various biotic agencies. Therefore, height of the regenerating seedlings is an important parameter for judging the stage of natural regeneration. FAO (1994) reported that the seedlings at 30 cms. height were often referred as "established regeneration" and those below were noted as "potential regeneration". However, this classification system should be adopted or modified as per local conditions. *Rhizophora* propagules for instance may well exceed 30 cms. in length without being considered "established regeneration".

In Bakultala, Rangat and Long Island Ranges (Figures- 3.4, 3.5 and 3.7 respectively), number of seedlings in each of the four height classes i.e. 0-30, 31-60, 61-90 and 91-120 cms. showed that as the height of seedlings increased their number decreased. In Bakultala and Rangat Ranges large number of seedlings were there in 0-30 cms. height class and it was natural for many seedlings to die in the process of natural competition for food, light and space. Overall natural regeneration pattern of Betapur Range is shown in Figure-3.6. Number of seedlings present in 61-90 cms. height class was conspicuously less than the seedlings present in other three height classes, which indicated towards some biotic/ abiotic agency that adversely affected the natural regeneration. In addition to biotic reasons, closed canopy also hinders the natural regeneration of mangroves. Seth & Mathauda, (1957) observed that mangrove seed production was abundant each year in many areas but seedlings did not survive under normal heavy canopy. Preparatory fellings were helpful in such areas for promotion of natural regeneration. Comparative state of natural regeneration of mangroves in different ranges of Middle Andaman Forest Division has been represented in the Table- 3.29.

TABLE- 3.29

COMPARATIVE STATE OF NATURAL REGENERATION OF MANGROVES IN DIFFERENT RANGES OF MIDDLE ANDAMAN FOREST DIVISION

S.N.	Name of the species	Bajalungta	Bakultala	Rangat	Betapur	L.Island
1.	*Rhizophora apiculata*	G	G	G	M	G
2.	*Rhizophora mucronata*	G	G	P	P	G
3.	*Bruguiera gymnorrhiza*	P	G	M	M	P
4.	*Ceriops tagal*	G	-	G	G	G
5.	*Avicennia officinalis*	G	G	-	-	G
6.	*Avicennia marina*	G	G	G	M	G
7.	*Excoecaria agallocha*	M	G	M	P	P
8.	*Acrostichum aureum*	G	G	G	G	-
9.	*Lumnitzera littorea*	G	G	P	P	G
10.	*Xylocarpus granatum*	P	P	P	-	-
11.	*Xylocarpus moluecensis*	P	P	P	-	-
12.	*Nypa fruticans*	G	-	-	P	-
13.	*Phoenix paludosa*	G	G	G	G	G
14.	*Heritiera littoralis*	P	G	P	P	P
15.	*Aegiceras corniculatum*	G	-	-	-	-
16.	*Sonneratia alba*	M	P	P	-	M
17.	*Sonneratia caseolaris*	-	P	P	M	-
18.	*Acanthus ilicifolius*	-	G	-	-	-
19.	*Lumnitzera racemosa*	-	P	P	-	G

Index:

G = Good Natural Regeneration M = Moderate Natural Regeneration

P = Poor Natural Regeneration - = Species not significant in the range from occurrence point of view

3.4.3. ESTIMATION OF AREA UNDER MANGROVES

By following first method i.e. toposheet method coupled with ground truthing, the area under mangroves was computed as 13,006 ha (Tables-3.18 and 3.19) while by following second method i.e. remote sensing map it was computed as 9188 ha. This variation may be due to following reasons.

1. Toposheets have been prepared on the scale 1:25,000, while remote sensing map is on the scale of 1:1,25,000. Patches of mangroves below 25 ha in an area are not recorded in satellite picture, which may be the main reason for variation in mangrove area calculated by two different methods.

2. Some mangrove areas for example Flat Island, Cone Island, Guitar Island etc have not been shown on Remote Sensing map.

3. There is no clear-cut demarcation of Divisional Boundary / landmarks on the Remote Sensing map.

4. There are chances of error in visual interpretation of Satellite imagery to prepare forest type map.

On the basis of ground truthing and scale of maps it can be said that the first method i.e. toposheet method coupled with ground truthing is much more accurate than the method using forest type map prepared on the basis of visual interpretation of satellite imagery.

As per the records of the Environment and Forests Department (Anonymous, 1997), the total mangrove area under the Middle Andaman Forest Division is 23,394.55 ha. The area was calculated by visual interpretation of satellite imagery of March 1986 and September 1987 and area computation was made by the graph sheet and dot grid method (Anonymous, 1987). No ground truthing was carried out in this case.

Official figure of 23,394.55 ha mangrove area seems to be on much higher side as compared to an area of 13,006 ha, computed during course of present study for the Middle Andaman Forest Division, on the basis of toposheet method **coupled with ground truthing**. This variation may be due to the following reasons.

a) Part of Middle Andaman Main Island is also under territorial jurisdiction of Mayabunder Forest Division. Therefore, some mangrove area under Mayabunder Forest Division might have been included in the mangrove area of Middle Andaman.

b) Accuracy of the results also depends on the methodology followed.

c) There are chances of human error in calculation.

d) Merging of mangrove vegetation with terrestrial vegetation while interpreting the satellite imagery.

e) Extensive ground truthing was not done by the earlier workers while assessing the mangrove area.

Results obtained from the present study are reliable in view of the methodology followed. During the course of extensive and intensive field- work, at many places much lesser area under mangroves was found as compared to the official records of the Forest Department. Therefore, a copy of the field report was also submitted to the Principal Chief Conservator of Forests (A& N Islands) for his perusal and further necessary action.

Mangrove area of Andaman and Nicobar Islands were estimated by various person/agency and their estimates were as follows:

Mathauda (1957) - 11,650 ha ; Waheedkhan (1957) - 1,20,180 ha

Sahni (1957) - 1,17,100 ha; Sidhu (1963) - 1,15,200 ha

Blasco (1975) - 1,15,000 ha; Untawale (1987) - 1,15,000 ha

Balakrishnan (1989) - 1,01,172 ha

Forest Survey of India (1987) - 68,600 ha

Forest Survey of India (1989) - 97,300 ha

Forest Survey of India (1991) - 97,100 ha

Forest Survey of India (1993) - 96,600 ha

Forest Survey of India (1995) - 96,600 ha

Forest Survey of India (1997) - 96,600 ha

The total mangrove areas of different regions of Andaman and Nicobar Islands, as reported in the Working Plans of Forest Department, is 77, 769 ha and its break-up is as follows-

North Andaman - 29,701 ha; Middle Andaman - 23,100 ha

Baratang - 8,519 ha; South Andaman - 12,870 ha

Little Andaman - 1,124 ha; Nicobars - 2,455 ha

Space Application Centre (SAC), Ahmedabad has reported the mangrove areas in the Andaman & Nicobar Islands as 77,050 ha (Anonymous, 1992). Mangrove coverage in the Andaman & Nicobar Islands was calculated at 77,770 ha by visually interpreting and delineating mangrove areas from satellite imagery of March, 1986 and September, 1957. Area computation was made by graphsheet and dot grid method (Bandopadhyay, 1992). According to Chengappa (1944), the area under mangrove forest is nearly 44,330 ha.

Forest Survey of India (FSI) gave an estimate of the area under mangrove vegetation in the country, for the first time in 1987. The studies were based on interpretation of satellite data. The FSI has since been monitoring the area under mangroves in biennial cycle (1989, 1991, 1993 and 1995). The 1987 assessment was based on interpretations of 1:1 million scale satellite data, whereas subsequent interpretations are based on 1:250,000 scale satellite data (Anonymous, 1995, 1997)

It can be seen from these results that the mangrove area, as estimated by various person/ agency vary widely, which points out towards the necessity of extensive ground truthing of all the mangrove areas. Inadequate information on the survey methodology used makes it unclear whether the variation in different estimates is due to the rapid rate of deforestation, reclamation and natural destruction, or is as a result of different techniques used, or due to both.

PLATE: 3.3

A lush green patch of mangroves at Timber Ghat Depot, Yerrata, Middle Andaman

PLATE: 3.4

A scenic view of mangrove forest in Middle Andaman

3.4.4. ESTIMATION OF EXPLOITABLE GROWING STOCK AND STAND STRUCTURE OF MANGROVES

The total area of the Indian mangroves, has been estimated to be approximately 7,00,000 ha (Sidhu, 1963). This is about 7% of the world's mangroves. The East Coast of India has about 80% of Indian mangroves, while the West Coast has only 20% (Untawale, 1984). This is mainly because of the geomorphological characteristics of the coast. The Andaman and Nicobar Islands have comparatively virgin mangrove forests, because of remoteness and less human interference. Mangroves of West Coast of India are considered as the degrading type mainly because of biotic and abiotic factors (Blasco, 1975, 1977; Untawale, 1980). Lush green tracts of almost undisturbed mangroves are common in Middle Andaman (Plates- 3.3 and 3.4)

As per the Forest Survey of India's report on Forest Resources of Middle Andaman (1981), the growing stock of mangroves was 105.552 m3 per ha. On the basis of present study average exploitable growing stock of mangroves in Middle Andaman Forest Division has been calculated as 163.530 m3 per ha. (Table-3.30). The average stem volume for Goa mangroves was estimated to be 63 m3 per ha (Jagtap, 1985) as compared to the stem volume of 248 m3 per ha for the best stands in Malaysia (Noakes, 1951). According to Sahni (1957), the mangrove timber yield in Andamans is about 8000 cft per acre. Waheed Khan (1957) estimated that the mean annual increment for timber was 7 cft per acre and the growing stand of timber from Sunderbans mangrove forest had been calculated to be 40, 32,000 tonnes

There is an increase in average growing stock of mangroves per ha in Middle Andaman as compared to the growing stock reported by FSI in the year 1981, which may be due to the following reasons:

a) In the last 17 years (between 1981 and 1998) natural growth of vegetation has taken place.

b) In the last 10 years, lot of emphasis has been given on conservation of mangroves and its felling has been banned since 1987, apart from taking several measures to restore mangroves to their pristine glory.

c) Lot of awareness has come among masses regarding importance of mangroves and the people's role in protection of mangroves.

TABLE- 3.30

EXPLOITABLE GROWING STOCK OF MANGROVES IN DIFFERENT FOREST RANGES OF MIDDLE ANDAMAN DIVISION

S.N.	Forest Range	Calculated mangrove area (ha)	Calculated average exploitable growing stock (m3/ha)	Total exploitable growing stock (m3)
a	b	c	d	e = c X d
1.	Bajalungta	9721	171.736	16,69,445.656
2.	Bakultala	860	191.043	1,64,296.980
3.	Rangat	1524	185.222	2,82,278.328
4.	Betapur	280	38.796	10,862.880
5.	Long Island	621	65.555	40,709.655
	TOTAL	13,006		21,26,883.844

Average exploitable growing stock = 21,26,883.844 ÷ 13,006 = **163.530 m3/ha**

Sustainable Extraction of Mangroves

A well-managed mangrove forest can give sustained yield of firewood and timber. The rotation period and the annual cut determine it. Mangrove forests of Andaman and Nicobar Islands were worked under shelterwood system keeping a rotation period of 30 years (Balachandra, 1988). Annual cut can be determined either through area control or volume control.

Annual cut under area control system can be determined by using following formula:

AC=A/R

Where, AC= Annual cut in ha/year

A= Total productive forest area in ha

R= Rotation in years

In case of Middle Andaman Forest Division

AC= 13,006/30

= 433.53 or say 434 ha/ year

Annual cut under volume control method can be determined by using **Von Mantel's formula** given below. The value of this formula lies in its simplicity, the small amount of data required for its use and as it gives conservative results.

AC= 2 (GS/R)

Where, AC= Annual cut (m3/year)

GS= Growing stock (m3)

R= Rotation (in years)

In case of Middle Andaman Forest Division average exploitable growing stock is 163.530 m3/ha and total growing stock is 21,26,884 m3 in an area of 13,006 ha as calculated during this study. Therefore,

AC= 2 (21,26,884/30)

= 1,41,792 m3/ year

or AC = 1,41,792/13,006

= 10.90 m3/ ha/ year

According to Balachandra (1988) yield of mangroves varies from place to place, the average yield from the South Andaman, Middle Andaman and North Andaman being 59m3/ha, 105m3/ha and 115m3/ha respectively. *Rhizophora* species and *Bruguiera* species contribute more to the yield. In South Andaman Forest Division, *Rhizophora* contribute more to the yield whereas *Bruguiera* species contribute more to the yield in the Middle Andaman and North Andamans. He further reported that maximum yield was obtained in the diameter class 10-20 cm in all the species. Standing biomass of two natural strands of mangrove forests, one dominated by species of *Rhizophora* only and the other having mixed association of species of *Bruguiera, Lumnitzera, Avicennia, Rhizophora, Sonneratia* and the *Xylocarpus* was found to be 124 and 214 t/ha, respectively (Mall *et al.*, 1991).

Mangroves grow rapidly under suitable conditions and can yield over 270 m3 per ha within 30 years equivalent to an MAI of 9-10 m3 per ha (FAO, 1994)

As far as **stand structure** in mangroves is concerned, the situation varies from range to range. In Bajalungta Forest Range significant number of mangrove plants are present in all the girth classes. This indicates that by and large considerable number of plants are able to establish and reach to maturity stage. Tall trees of mangroves are common in many areas. At Kadamtala (Middle Andaman), height of *Bruguiera gymnorrhiza, Lumnitzera littorea, Avicennia marina, Rhizophora mucronata* and *R. apiculata* was noted from 30 to 45 meters (Singh *et al.*, 1986).

Maximum number of plants are there in the girth class 21-30 cms. (Figure- 3.14). In Bakultala Forest Range also mangroves are present in all girth classes but in 0-10 cms. girth class the number of plants are abnormally low. This indicates that young seedlings are not getting established. Maximum plants are there in 11-20 cms. girth class (Figure- 3.15). In Rangat Forest Range considerable number of plants are there in all the girth classes. Maximum plants are there in 0-10 cms. girth class (Figure- 3.16). In Betapur Forest Range exceptionally large number of plants are there in 0-10 cms girth class while in other classes plants are very less in number. This clearly indicates that natural regeneration is not getting established in this area also. There are only few trees, which are able to reach maturity (Figure-3.17). In Long Island Forest Range mangroves are present in all the girth classes. Maximum plants are there in 11-20 cms. girth class. There are few number of trees above 80 cms. girth (Figure- 3.18). Average growing stock of mangroves in different ranges of Middle Andaman Forest Division has been shown in Figure-3.19.

In Goa, the average stand density ranged from 461 trees per ha along Mandovi estuary to 857 trees per ha along Galgibag estuary (Jagtap, 1985), which was very low as compared to stand density at Andamans (Mall *et al.*, 1982). The major mangrove formations in Goa occur along the Mandovi, Zuari, Cumbarjua estuarine complex and Galgibag estuary. These estuaries in Goa show a high stand volume of *Avicennia officinalis* as compared to *Rhizophora* and *Sonneratia* species (Jagtap, 1985).

In general, maximum number of plants are there in lower girth classes and as the plants move towards higher girth classes their number decreases. This is a natural phenomenon. Many plants perish in the process of competition among the plants itself for food, light and space etc. This statement is also further substantiated by the work of Balachandra (1988) who reported information on the number of mangrove stems and yield for Middle Andaman (Table- 3.31).

TABLE- 3.31

MANGROVE STEMS AND YIELD IN MIDDLE ANDAMAN

Diameter classes	Number of stems	Yield (m3/ha)
1-10	222.9	2.3
11-20	397.7	37.5
21-30	88.0	33.9
31-40	19.4	15.6
41-50	3.4	9.9
51-100	3.4	21.6
Total	**734.8**	**120.8**

SOURCE: Balachandra (1988)

3.4.5. UTILISATION

Although there are several uses of mangrove species, however, at present there is no extraction of mangroves as per the policy decision taken by the Government of India. Mangrove forests in Andaman and Nicobar Islands were worked upto 1986 (Anonymous, 1997).

Mangroves have been used as fuel wood and as transmission poles in Andaman and Nicobar Islands since 1957 when penal settlement started in Andaman (Balachandra, 1988).

Because of its high calorific value mangrove fuel was used to propel marine crafts, to generate electricity in powerhouse and as a source of energy in plywood industries, hotels, bakeries and for domestic needs (Banerji, 1957).

The year-wise extraction figures of mangrove fuel wood from various forest divisions from 1980-85 are furnished in Table- 3.32. Part of the mangrove wood was converted into charcoal, which is in great demand, by the washermen, bakers and others. Data given in the Table- 3.32 reveals that extraction of mangrove wood in Andaman and Nicobar decreased from year to year, in general. This may be due to conservation oriented policies of the government and switch over of the people from mangrove fire wood to other forms of fuel like LPG and kerosene etc. Mangrove poles were being used in construction of huts and platforms of jetties. However, there was general increase in production of charcoal produced from mangrove wood.

In earlier days, poles of *Brugulera* spp. were used as transmission lines after treating with Creosote. These transmission poles served the purpose for 10 years (Banerji, 1957).

For the manufacture of craft paper *Rhizophora mucronata, R. apiculata* and *Bruguiera gymnorrhiza* were found suitable but, so far no attempt has been made to utilize the mangrove for this purpose on commercial lines. Similarly, the bark and the leaves of mangrove are a good source of tannin, but so far no extraction has been done for this purpose on commercial lines (Dagar *et al.,* 1991).

Mangrove bark especially from *Bruguiera* species is suitable for preparing adhesive for composite woods. It is estimated that crops of *Bruguiera* species in Andamans could yield per annum about 20,000 tons of bark in addition to about 80,000 tons of wood (Mathauda, 1957).

To some extent mangrove leaves (*Avicennia* spp) are used as a source of feed for the cattle, which graze in mangroves area during low tides (Dagar *et al.*, 1991).

The mangrove swamps constitute a valuable asset to the Andaman- Nicobar Islands and if properly managed will prove to be a permanent source of income to the people and government (Sahni, 1957)

TABLE- 3.32

EXTRACTION FIGURES OF MANGROVES IN DIFFERENT DIVISIONS

Forest Division	By Govt. agency (m^3)	On payment of Royalty (m^3)	Total (m^3)	Charcoal (Tons)
1981-82 South Andaman	-	20586	20586	-
Baratang	130	207	337	3.92
Middle Andaman	157	4405	4562	7.560
North Andaman	-	472	472	0.960
Nicobar Division	-	104	104	-
TOTAL	287	25774	26061	12.440
1982-83 South Andaman	-	15314	15314	-
Baratang	100	65	165	3.61
Middle Andaman	150	567	717	9.55
North Andaman	-	1739	1739	0.71
Nicobar Division	22	-	22	-
TOTAL	272	17685	117957	13.87
1983-84 South Andaman	-	12277	12277	-
Baratang	127	70	197	4.34
Middle Andaman	1394	1285	2677	7.12
North Andaman	-	545	545	-
Nicobar Division	-	-	-	-
TOTAL	1519	14177	15696	11.66
1984-85 South Andaman	-	11059	11059	-
Baratang	130	19	149	4.69
Middle Andaman	8	-	8	8.51
North Andaman	11	2639	2720	1.27
Nicobar Division	-	28	28	-
TOTAL	219	13745	13964	14.47

SOURCE : Annual reports A&N Forest Department.

3.4.6. MANGROVE CONSERVATION AND MANAGEMENT SCENARIO IN ANDAMAN AND NICOBAR ISLANDS

In the past mangrove firewood and poles were extracted on a small scales to meet the local demand of the people. In addition to these one powerhouse at Port Blair and three major ply wood industries namely M/S Kit ply, M/S Jayshree Timber Products and M/S Andaman Timber Industries were using mangrove fuel for their boilers. Even Government's steam vessels were using mangrove fuel for generating steam. Limited extraction of mangroves did not cause any damage to the mangroves in the Government forests but in the Revenue areas, the destruction of mangroves is conspicuous and at places the area has been reclaimed for agriculture as well as for settlement (Anonymous, 1997).

Although systematic working for mangrove forest was prescribed in the working plan, the extraction of mangrove fuel woods and poles was carried out on small scale due to limited demands. With the growing awareness on conservation of mangroves, the Andaman and Nicobar administration has banned extraction of mangroves since 1987. The Ply wood industries, powerhouse and Government's steam vessels have since switched over to diesel (Sinha, 1994).

The strategy adopted in Andaman and Nicobar Islands for the conservation and management of mangrove forests is as follows (Anonymous, 1997) -

1. Full protection to the mangrove flora and fauna by banning mangrove extraction from Government forests.

2. Identification of potential mangrove areas for declaring as National Parks and Sanctuaries.

3. Eco-restoration of degraded and critical mangrove areas by afforestation of suitable species.

4. To identify endangered mangrove species and provide full protection for their rehabilitation.

5. To check encroachment, destruction and reclamation of mangrove areas by effective measures.

6. To monitor the changes in mangrove areas, its floristic and faunal composition and physiographic changes.

7. Awareness amongst the public on the importance of mangroves and the need for its preservation by education of the village folk.

8. Protection measures to keep vigil on possible destruction of mangroves.

3.4.6.1. MANGROVE CONSERVATION AND MANAGEMENT SCENARIO IN MIDDLE ANDAMAN FOREST DIVISION

Mangrove Management has been incorporated in the Working Plan for the Middle Andaman Forest Division for the period from 01.04.1993 to 31.03.2005 prepared by the Environment & Forest Department, Andaman &Nicobar Administration. The Government of India duly approved the Working Plan (Basu, 1994). Mangroves have been placed under Protection Working Circle.

The Protection Working Circle comprises of forest areas reserved as catchment areas for water reservoirs, Tribal (Jarwa) Reserve, National Parks, Wildlife Sanctuaries and small islands as well as other areas which are not silviculturally available nor economically feasible for intensive management and harvesting. This includes **mangrove forest areas** within the division and also the rugged and broken ground as well as precipitous slopes liable for erosion, situated within the Conversion Working Circle but not separately demarcated.

The special objects of management are to preserve the mangrove forest areas by offering total protection to the ecosystem and to regenerate and rehabilitate the degraded and denuded areas.

Critical review of mangrove conservation and management practices in Middle Andaman

Working Plan (Basu, 1994) broadly prescribes for protection and restoration of degraded mangrove forest. The Forest Department has ensured protection of mangrove forests but no systematic and planned works have been done for restoration of degraded mangrove areas. Working Plan does not speak about education and awareness programme to involve local people in the mangrove management, which is need of the hour. It is a fact that mangrove forest can not be fully protected by limited resources of Forest Department due to their wide distribution and scattered nature. Similarly, Working Plan does not speak about the research and training aspects of mangrove ecosystem. However, some officials of Forest Department have carried out some research works at their own initiative.

Felling in mangrove forest was banned in Andaman and Nicobar Islands in the year 1987 (Basu, 1994) and since then about 13 years have already passed but no studies have been carried out to review the state of mangrove forests. Actually, this study can help the policy makers to decide whether total ban on mangrove felling is still required or exploitation of fuel wood, timber and poles etc. can be started on sustained yield basis and without adversely affecting the environment to meet the genuine demand of the local people. In Middle Andaman, Murugan Puja is performed by masses in the month of April every year. During this puja, people walk on the burning charcoal made up of mangrove wood. It is not proper to deny supply of mangrove firewood for such genuine cause associated with people's religious, social and cultural sentiments

Mangrove forests have tremendous economic potential, which remain untapped in the absence of appropriate management plan and its implementation (Personal observation).

CHAPTER-4

CHARACTERISTICS OF FLOWERING, FRUITING AND GERMINATION OF MANGROVES

CHAPTER-4

CHARACTERISTICS OF FLOWERING, FRUITING AND GERMINATION OF MANGROVES

4.1. INTRODUCTION

Rehabilitation of degraded mangrove areas is one of the most important components in all the Mangrove Management Plans of various states and union territories. Whereas low and moderately degraded areas can be restored in most of the cases by promoting natural regeneration in the area, a severely degraded mangrove area calls for artificial regeneration for its quick restoration. Information on characteristics of flowering, fruiting, planting material and germination in various species of mangroves is necessary so as to plan timely collection of seeds/ fruits/ propagules for raising successful nurseries and plantations (Wafer, 1987).

Ecological aspect of mangroves of Andaman and Nicobar have been studied by Singh *et al.*, (1986, 1987); Ellis, (1987); Dagar, (1987); Rao and Chakraborti, (1987). Botanical Survey of India conducted studies on the ecology of the Indian Coastal Vegetation (Rao *et al.*, 1972 and 1974). Parkinson (1972) brought out a Forest Flora of Andaman Islands. Most of the earlier literature discussed about flowering and fruiting periods of mangroves but the detailed and specific information about Middle Andaman was lacking. In order to fulfil this information gap and to collect much other useful information related to flowering, fruiting and germination in mangroves, the work was carried out.

4.2 MATERIAL AND METHODS

To collect the information on flowering and fruiting various mangrove areas were frequently and extensively inspected using vehicle, boat and by walking. The exercise was conducted for more than one year so as to record various yearly phenomenon of flowering and fruiting periods. In case of propagules producing mangrove species fruiting period includes both the period of fruit and propagule formation. In most of the mangrove species sporadic flowering and fruiting can be seen here and there throughout the year but main flowering and fruiting period as observed during the study has been recorded.

To find out the time taken by the different species from budding stage to mature planting material (fruit or propagule) stage, 10 trees of each were selected and regular observations on stage of growth and maturity were taken in respect of individual bud, flower, fruit or fruit bunch and propagule.

To collect information on average number of propagules/seeds per kg and lengths of propagules, following methodology was adopted. In respect of propagules producing mangroves, 1000 number of healthy propagules of each species were collected. In case of each species length of all the 1000 propagules was measured so as to find out minimum, maximum and average length. The propagules of a particular species were thoroughly mixed and taken out randomly to find out number of propagules per kg. The same exercise was repeated ten times to find out average number of propagules per kg. In case of genus *Avicennia* and *Lumnitzera* 10 kg of fruits were collected and thoroughly mixed. Then the fruits were randomly taken out to find out the number of fruits per kg. The exercise was repeated ten times to find out average number of fruits per kg. Similar exercise was repeated by collecting 20-kg fruits of *Nypa fruticans* and *Heritiera littoralis* each and 50-kg seeds of *Xylocarpus granatum*. In case of *Phoenix paludosa, Excoecaria agallocha* and *Sonneratia alba* similar exercise was conducted by collecting 5-kg seeds of each species.

Characteristics of mature propagules/ fruits/ seeds were recorded based on the field observations.

To collect the information on germination characteristics, 1000 number of planting material (seed, fruit or propagule as the case may be) of each species were collected and sown in the area located in the natural habitat of a particular mangrove species. Daily observations were taken in the areas to know the germination period and germination percentage. Survival percentage was calculated after a period of six months from the date of sowing.

The entire study presented in this chapter was carried out in Middle Andaman, however, the data on flowering and fruiting periods of mangroves was also collected from Goa.

4.3 RESULTS

Results obtained on flowering and fruiting in mangroves of Middle Andaman are given in the Table-4.1. The table gives information on the period of the calendar year when floral buds, flowers and fruits/ propagules appear on a particular mangrove species. Figure- 4.1 presents the time duration in number of days, which is taken by a bud to reach to the stage of a mature fruit/ propagule in respect of various mangrove species. As far as flowering and fruiting in mangroves is concerned, it can be seen in one species or another, at one place or another throughout the year. However, degree of activity varies with time and place.

In Middle Andaman, budding and flowering in *Rhizophora apiculata* takes place during August to March and fruiting/ propagule formation takes place during January to July. Thus, it is seen that in *Rhizophora apiculata* some phenomenon related to flowering and fruiting can be seen throughout the year. In *Rhizophora mucronata* budding and flowering takes place during September to February and fruiting/ propagule formation takes place during January to June. Among propagule producing mangroves, this species takes maximum average time of 154 days for a floral bud to reach to the stage of mature propagule. In *Bruguiera gymnorrhiza* and *B. sexangula* budding and flowering takes place during June to January and fruiting/ propagule formation takes place during October to May. Both these species of the genus of *Bruguiera* take average time of 115 and 112 days respectively from floral bud stage to mature propagule stage. In *Bruguiera parviflora* budding and flowering takes place from February to April while fruiting/ propagule formation takes place during April to May. It takes an average period of 72 days from bud to mature propagule stage. It can be seen that as compared to *Bruguiera gymnorrhiza* and *B. sexangula,* it takes much lesser time from bud to mature propagule stage. It is also important to mention here that the propagule availability period in *Bruguiera parviflora* is of very short duration as compared to other species of the genus *Bruguiera.*

In *Avicennia officinalis* and *A. marina* budding and flowering takes place during May to July and fruiting takes place during August to October. In *Excoecaria agallocha* budding, flowering and fruiting take place during July to August. On an average it takes a period of 33 days from bud to mature fruit stage which is a very short period as compared to other mangrove species. Changes from bud to mature fruit are very fast and remarkable in this species. In *Lumnitzera littorea* and *L. racemosa* budding and flowering takes place during October to February and fruiting takes place during January to April which is more less same as in the case of *Ceriops tagal.* In *Phoenix paludosa* budding, flowering and fruiting take place during April to May. On an average it takes a period of 35 days from bud to mature fruit stage. This is another species like *Excoecaria agallocha* where fruits develop very fast. The fruits are available for a short duration (Table- 4.1). Period of flowering and fruiting of mangroves in Goa has been shown in Table-4.2 as observed during the study.

Plates 4.1- 4.6 show flowers in *Rhizophora apiculata, R. mucronata, Heritiera littoralis, Lumnitzera littorea, Avicennia officinalis* and *Bruguiera sexangula* respectively.

TABLE- 4.1

FLOWERING AND FRUITING PERIOD IN MANGROVES OF MIDDLE ANDAMAN

S.N.	Species	Budding & Flowering	Fruiting/ propagule formation	Bud to mature fruit/ propagule (Days)
1	*Rhizophora apiculata*	Aug.-Mar.	Jan.-July	145
2	*Rhizophora mucronata*	Sept.-Feb.	Jan.-June	154
3	*Bruguiera gymnorrhiza*	June-Jan.	Oct.-May.	115
4	*Bruguiera sexangula*	-do-	-do-	112
5	*Bruguiera parviflora*	Feb.-Apr.	Apr.- May	72
6	*Ceriops tagal*	Oct.-Feb.	Jan.-May	96
7	*Aegiceras corniculatum*	Mar.-May	May-Aug.	78
8	*Avicennia officinalis*	May-July	Aug.-Oct.	93
9	*Avicennia marina*	-do-	-do-	96
10	*Excoecaria agallocha*	July-August	July-August	33
11	*Lumnitzera littorea*	Oct.-Feb.	Jan.-Apr.	84
12	*Lumnitzera racemosa*	-do-	-do-	80
13	*Xylocarpus granatum*	June-Aug.	Sept.-Nov.	111
14	*Nypa fruticans*	Aug.-Sept.	Oct.-Dec.	94
15	*Heritiera littoralis*	Aug.-Nov.	Oct.-Jan.	75
16	*Phoenix paludosa*	April-May	April-May	35
17	*Sonneratia alba*	Aug.-Nov.	Nov.-Feb.	90
18	*Sonneratia caseolaris*	-do-	-do-	92
19	*Acanthus ilicifolius*	Apr.-May	May-June	49
20	*Acanthus volubilis*	-do-	-do-	54

Figure-4.1 Fruit/Propagule maturity periods in mangroves of Middle Andaman

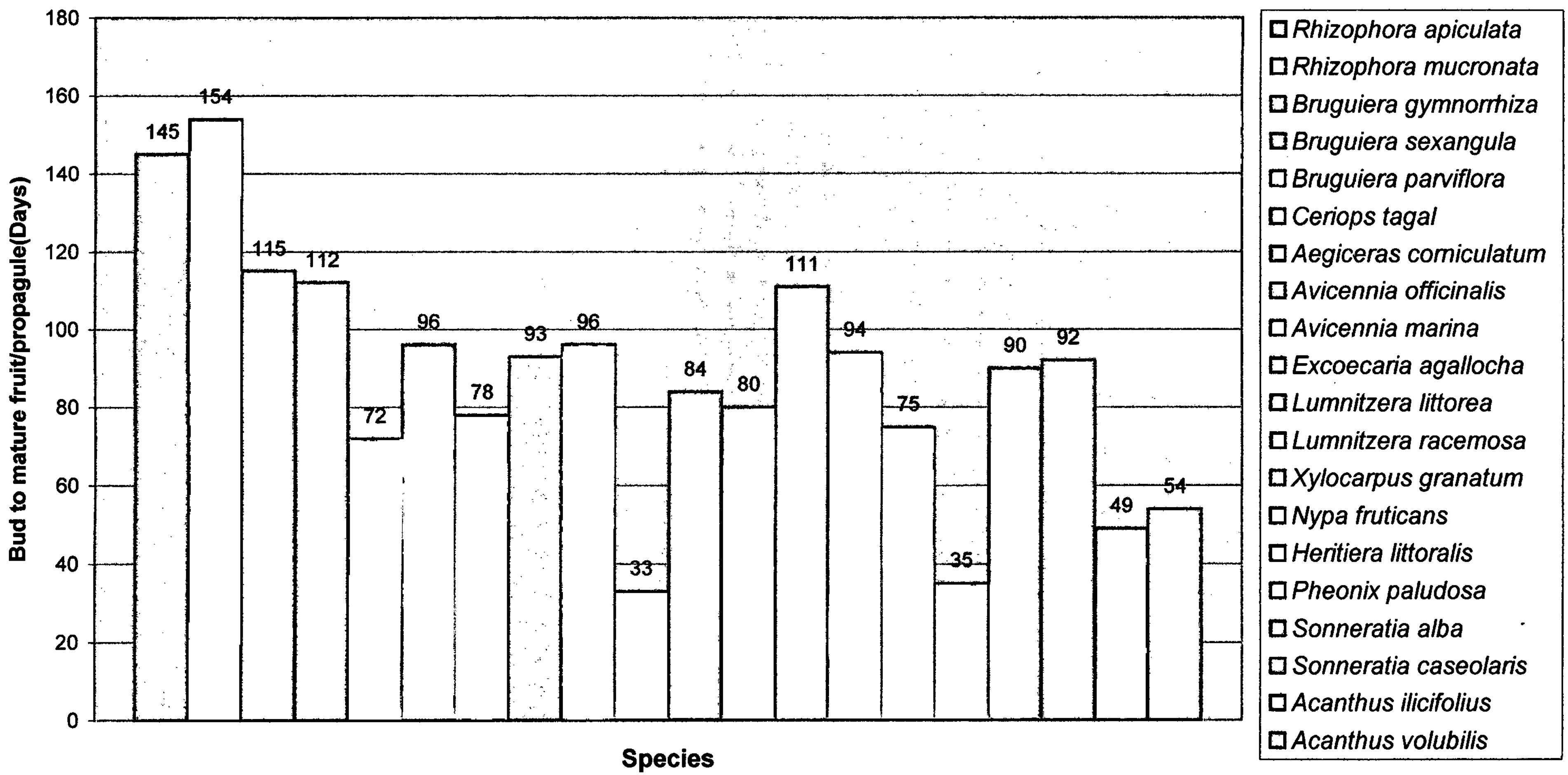


TABLE-4.2

PERIOD OF FLOWERING AND FRUITING OF MANGROVES IN GOA

S. N.	Species	Period of Flowering and Fruiting
1.	*Rhizophora mucronata*	March - July
2.	*Rhizophora apiculata*	March - July
3.	*Avicennia officinalis*	May – August
4.	*Avicennia marina*	May - August
5.	*Avicennia alba*	May - August
6.	*Sonneratia alba*	April - June
7.	*Sonneratia caseolaris*	April - June
8.	*Bruguiera gymnorrhiza*	March – June
9.	*Bruguiera cylindrica*	March - June
10.	*Kandelia candel*	March - June
11.	*Acanthus ilicifolius*	April - July
12.	*Excoecaria agallocha*	July - August
13.	*Ceriops tagal*	April - June
14.	*Aegiceras corniculatum*	April - May
15.	*Derris heterophylla*	May - July

PLATE- 4.1

Flower of *Rhizophora apiculata*

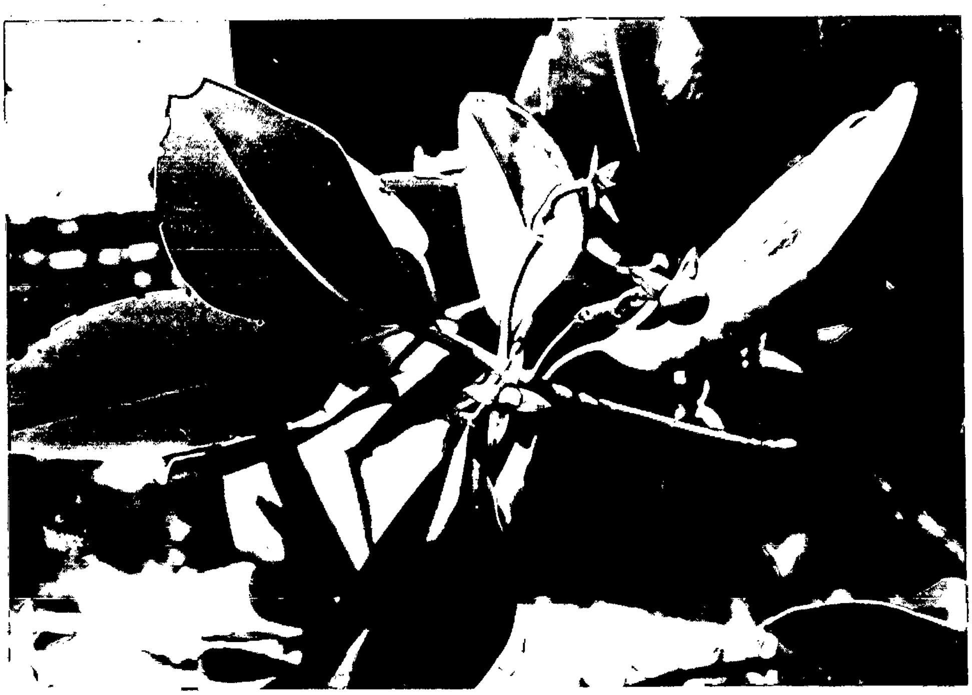


PLATE- 4.2

Flower of *Rhizophora mucronata*

PLATE- 4.3

Flowering in *Heritiera littoralis*

PLATE- 4.4

Flower in *Lumnitzera littorea*

PLATE- 4.5

Flowers in *Avicennia officinalis*

PLATE- 4.6

Buds and flowers in *Bruguiera sexangula*

Characteristics of various planting materials of mangroves like fruits, seeds and propagules have been shown in Table-4.3. This table indicates as to what material is collected and used for planting various species of mangroves. It also gives information on number of seeds per fruit and average number of seeds per kilogram in different species of mangroves. It further gives information on average length and length range in case of propagules of various mangrove species.

The species belonging to the genera *Rhizophora, Bruguiera, Ceriops* and *Aegiceras* produce one propagule per fruit and the same is collected and used for planting. The species belonging to the genera *Avicennia, Lumnitzera, Nypa* and *Heritiera* also produce one seed per fruit. The fruit is collected and used in planting. In case of *Phoenix paludosa*, *Excoecaria agallocha*, *Xylocarpus granatum* and *Sonneratia alba* fruits are collected from the field but their seeds ,after separation, are used for planting. One fruit of *Sonneratia alba* contain 200-225 seeds. *Phoenix paludosa* and *Excoecaria agallocha* produce 1 seed per fruit and 3 seeds per fruit respectively. *Xylocarpus granatum* produces 9-15 seeds per fruit. During the study it was noted that fruits of *Xylocarpus granatum* always contain odd number of seeds.

TABLE- 4.3

CHARACTERISTICS OF FRUITS/SEEDS AND PROPAGULES OF MANGROVES IN MIDDLE ANDAMAN

S.N.	Species	Material collected for planting	Material used for planting	Number of seeds per fruit	Average number of material per kg. used for planting	Average length & length range in case of propagules (cms)
1	*Rhizophora apiculata*	Propagule	Propagule	1	34	30.5 (24.1-40.4)
2	*Rhizophora mucronata*	-do-	-do-	1	12	47.2 (40.7-74.3)
3	*Bruguiera gymnorrhiza*	-do-	-do-	1	37	15.3 (11.4-22.3)
4	*Bruguiera sexangula*	-do-	-do-	1	36	15.5 (12.0-21.9)
5	*Bruguiera parviflora*	-do-	-do-	1	440	7.5 (6.9-8.9)
6	*Ceriops tagal*	-do-	-do-	1	120	22.0 (18.0-29.0)
7	*Aegiceras corniculatum*	-do-	-do-	1	778	5.5 (4.6-6.9)
8	*Avicennia officinalis*	Fruit	Fruit	1	350	-
9	*Avicennia marina*	-do-	-do-	1	345	-
10	*Lumnitzera littorea*	-do-	-do-	1	9,228	-
11	*Lumnitzera racemosa*	-do-	-do-	1	9,045	-
12	*Nypa fruticans*	-do-	-do-	1	12	-
13	*Heritiera littoralis*	-do-	-do-	1	35	-
14	*Excoecaria agallocha*	-do-	seed	3	40,124	-
15	*Xylocarpus granatum*	-do-	-do-	9-15	13	-
16	*Sonneratia alba*	-do-	-do-	200-225	29953	-
17	*Phoenix paludosa*	-do-	-do-	1	8889	-

Table-4.4 mentions about mangrove species, which produce propagules. It also gives information on characteristics of mature propagules. Similarly, Table-4.5 gives list of mangrove species whose fruits/ seeds are used for planting. It further mentions characteristics of mature fruits/ seeds of various mangrove species.

Immature and mature propagules of *Bruguiera gymnorrhiza* are shown in Plate-4.7. Ripe fruits in *Phoenix paludosa* have been shown in Plate-4.8. Fruits of *Sonneratia alba, Excoecaria agallocha* and *Xylocarpus granatum* have been shown in Plates- 4.9, 4.10 and 4.11 respectively.

Table- 4.6 gives vital information on germination characteristics of various species of mangroves. It includes information on minimum and maximum germination time, germination percentage and survival percentage after six months. Minimum germination period is as early as 7 days in case of *Avicennia officinalis* and *A. marina* and as late as 90 days in case of *Xylocarpus granatum*. 100% germination was observed in *X. granatum* and *Nypa fruticans* while a low of 36 % germination was observed in *Lumnitzera littorea*. The Table-4.6 also mentions about survival percentage after six month from the date of sowing with reference to originally sown 1000 number of propagules/ fruits/ seeds. It is clear from the study that once the germination takes place, the chances of mortality are very low up to a period of six months of sowing. Graphical representation of minimum and maximum germination periods of mangroves in Middle Andaman is depicted in Figure-4.2.

TABLE-4.4
PROPAGULE PRODUCING MANGROVES AND THE CHARACTERISTICS OF MATURE PROPAGULES

S.N.	Name of the Species	Characteristics of mature propagule
1	*Rhizophora mucronata*	Yellowish coloured about 1.5cms. wide band (abscission collar) on the upper part of the propagule adjacent to pericarp develops on maturity. A thin yellowish colour band starts appearing which widens slowly as the maturity increases. Mature propagules can be plucked with slight application of force. Fully mature propagules will also fall on shaking the tree or branches. When the collar reaches about 1.5 cm in length, the propagule leaves the pericarp.
2	*Rhizophora apiculata*	Same as *Rhizophora mucronata*. The only difference is that the abscission collar is about 1 cm wide on full maturity.
3	*Bruguiera gymnorrhiza*	On maturity the hypocotyl changes its colour from green to dark brown. Mature propagules can be easily separated from pericarp. Abscission collar is not found.
4	*Bruguiera parviflora*	Same as *Bruguiera gymnorrhiza*
5	*Ceriops tagal*	About 1 cm wide yellowish colour abscission collar develops on maturity. On maturity propagule changes its colour from green to dark brown.
6	*Aegiceras corniculatum*	Propagules become pinkish to light brown on maturity. Mature propagules can be removed from mother tree with very little application of force.

TABLE- 4.5

FRUIT PRODUCING MANGROVES AND CHARACTERISTICS OF MATURE FRUITS AND SEEDS.

S.N.	Species	Characteristics of mature fruits and seeds
1	a) *Avicennia alba* b) *A. marina* c) *A. officinalis*	As the seeds mature wrinkles develop on seed coat and its colour changes from green to yellowish green. Mature seeds fall easily on shaking the branches.
2	a) *Sonneratia alba* b) *S. caseolaris*	On maturity fruits change its colour from light green to dark green with brown coloured patches. In mature fruits star shaped calyx can be easily separated from the fruit by application of little force. Outer layer of fruit develops cracks on maturity.
3	*Phoenix paludosa*	On maturity fruits change their colour from green to dark reddish brown. Mature fruit fall easily on shaking the plant.
4	*Nypa fruticans*	On maturity fruits becomes deep reddish brown in colour. Unlike immature fruits, mature fruits can be separated easily from the bunch with mild blow on the fruit bunch.
5	*Heritiera littoralis*	Fruit changes its colour from green to yellowish brown.
6	*Xylocarpus granatum*	On maturity fruit changes its colour from brown to dark leathery brown with unevenly distributed black spots. Fruit also starts developing two cracks on the top at right angle to each other, which ultimately results in breaking of thick fruit skin into four almost equal parts.

PLATE- 4.7

Immature (green coloured) and mature (brown coloured) propagules of *Bruguiera gymnorrhiza*

PLATE- 4.8

Ripe fruits in *Phoenix paludosa*

PLATE- 4.9

Fruits of *Sonneratia alba*

PLATE- 4.10

Fruits in *Excoecaria agallocha*

PLATE- 4.11

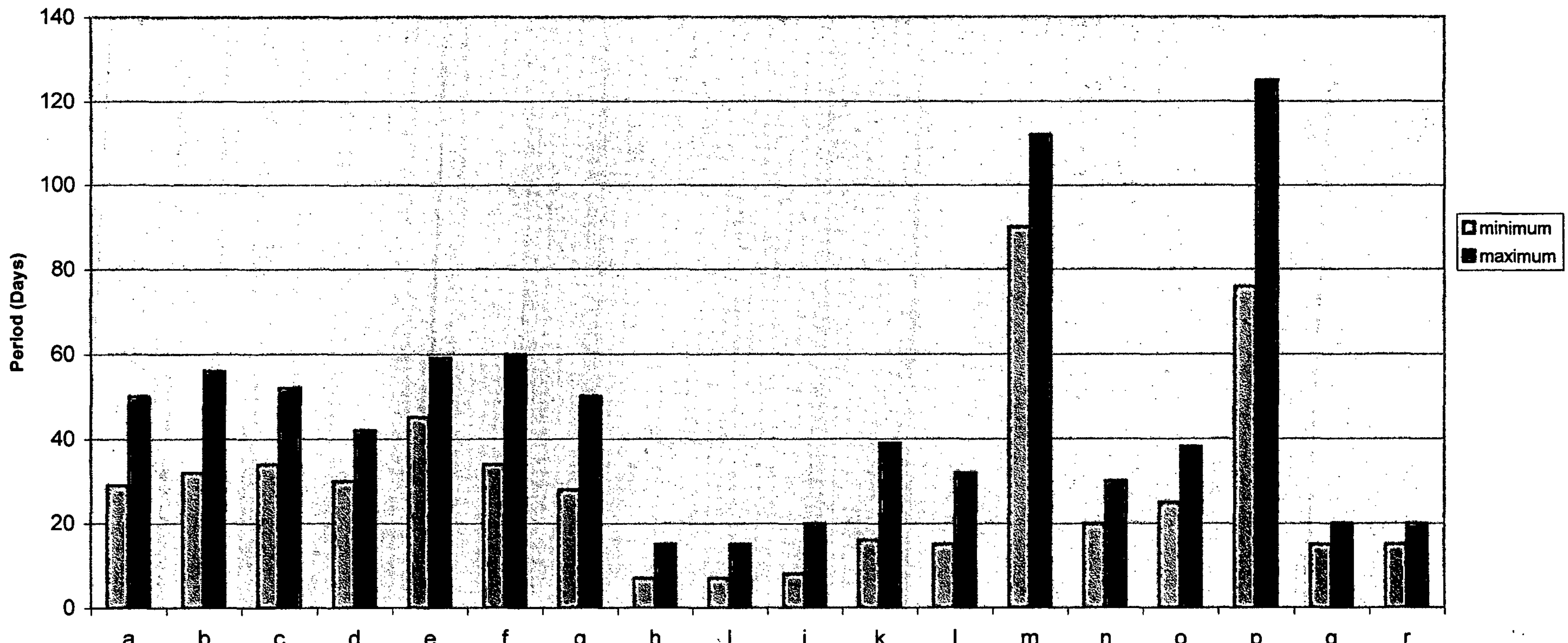
Fruit of *Xylocarpus granatum*

TABLE-4.6

GERMINATION CHARACTERISTICS IN MANGROVES OF MIDDLE ANDAMAN

S.N.	Species	Germination period (days)	Germination percentage (%)	Survival percentage after six months (%)
1	*Rhizophora apiculata*	29-50	98	98
2	*Rhizophora mucronata*	32-56	99	99
3	*Bruguiera gymnorrhiza*	34-52	88	82
4	*Bruguiera sexangula*	30-42	90	85
5	*Bruguiera parviflora*	45-59	69	61
6	*Ceriops tagal*	34-60	97	95
7	*Aegiceras corniculatum*	28-50	75	65
8	*Avicennia officinalis*	7-15	92	90
9	*Avicennia marina*	7-15	96	90
10	*Excoecaria agallocha*	8-20	70	65
11	*Lumnitzera littorea*	16-39	36	35
12	*Lumnitzera racemosa*	15-32	40	40
13	*Xylocarpus granatum*	90-112	100	100
14	*Nypa fruticans*	20-30	100	96
15	*Heritiera littoralis*	25-38	90	85
16	*Phoenix paludosa*	76-125	78	70
17	*Sonneratia alba*	15-20	72	72
18	*Sonneratia caseolaris*	15-20	75	71

Figure-4.2 Minimum and maximum germination period 0f mangroves in Middle Andaman.



Species: a=Rhiz.apic. b=R.mucr. c=Brug.gymn. d= [illegible]exa. e = B.parv. f=Ceri.taga. g=Aegi.corn.h=Avic.offi. I=A.mari. J=Exco.agal. k=Lumn.litt. l=L.race. m=Xylo.gra[illegible] n=Nypa frut.o=Heri.litt. p=phoe.palu. q=Sonn.alba r=S.case.

4.4 DISCUSSION

Most mangrove species flower and fruit regularly (FAO, 1994). When flowering and fruiting periods of different species of mangroves were compared between Middle Andaman and Goa (Tables- 4.1 and 4.2), it was found that this period was longer in Middle Andaman as compared to Goa in case of most of the mangrove species. The exception was *Acanthus ilicifolius*, whose flowering and fruiting was for a longer period in Goa as compared to Middle Andaman. *Excoecaria agallocha* was the only species whose flowering and fruiting period was same at both the places.

Wafar, (1987) studied development periods from bud to mature fruit in respect of various mangrove species in Goa (Table-4.7). These results can be compared with such deductions for the same species from Middle Andaman (Tables-4.1& 4.7) and other geographical regions of the world. *Rhizophora mucronata* and *Sonneratia alba* from both Middle Andaman and Goa show almost same development periods of 5 and 3 months respectively from bud to mature fruit stage. *Rhizophora apiculata* in Middle Andaman has the longer developmental period of 145 days as compared to the 120 days in Goa. In *R. apiculata* from Thailand development from flower to propagule took 4-6 months (Christensen and Wium-Andersen, 1977). *Avicennia officinalis* and *Ceriops tagal* have much shorter development periods of 93 and 96 days respectively in Middle Andaman as compared to the corresponding period of 150 and 120 days in Goa. Bud to mature fruit development period of *Avicennia marina* in Middle Andaman is 96 days while for *A. marina* from Thailand, it is 2 months (Wium- Andersen and Christensen, 1978). *A. marina* from South Africa, on the other hand, has a longer development period of 4 months (Steinke and Charles, 1984), but this may be due to distribution of this species, far away from the tropical zone.

TABLE-4.7

PHENOLOGICAL OBSERVATIONS ON MANGROVE SPECIES

S.N.	Species	Buds to mature fruits- Duration in months	Development of buds to fruits in Percentage
1	*Rhizophora apiculata*	4	14.0 % - 44.0 %
2	*Rhizophora mucronata*	5	6.0 % - 55.0 %
3	*Sonneratia alba*	3	-
4	*Sonneratia caseolaris*	-	66.0 % - 79.0 %
5	*Avicennia officinalis*	5	3.5 % - 90.0 %
6	*Kandelia candel*	4	-
7	*Ceriops tagal*	4	-

SOURCE: Wafer, (1987)

Phenological characteristics of mangrove species are related to different environmental factors, particularly to the amount of rainfall, temperature, soil and water conditions (Kongsangchai *et al.*, 1982). In the mangrove species along the Goa coast, extensive flowering was noticed during March to June and extensive fruiting during April to May. Flowering was generally poor or absent during September to January. An extensive flowering during March to June may be attributed to higher temperatures and longer duration of light (photoperiod) during these months, while extensive fruiting during April to July may be due to heavy rains. High temperatures and long photoperiods may be responsible for the excretion of some chemicals, which may induce flowering (Jagtap, 1985). The extensive fall and establishment of mangrove seedlings, particularly in the members of Rhizophoraceae, during rainy season may be due to reduced salt content of the plant tissue and their immediate environment. Genkel (1962) has suggested that excess salt in the soil delays the fall of seedlings in the mangroves. The propagules or seeds of mangroves are buoyant and are adapted to dispersal by waters (Tomlinson, 1971; Gill, 1975; Steinke, 1975; Robinowitz, 1975). The production number of seedlings and size of the mature propagules of mangroves in combination with tidal amplitude plays an important role in the zonation of the mangroves (Untawale *et al.*, 1980). Field observations at Tembilahan (Indonesia) indicate that mangrove fruits are available all year round but with a fruiting peak during certain months (Hong, 1996). The peak season varies from locality to locality.

In Costa Rica, *R. harrisonii* produce mature propagules mainly during June and July. In Sierra Leone, West Africa, the main fruiting season of *Rhizophora* *racemosa* coincides with the beginning of the rainy season in May-July and the ripe propagules are easily recognized by the appearance of a "collar" beneath the pericarp. In Malaysia, the principal *Rhizophora* species fruit during June to December. Preliminary studies indicate that most species flower and bear fruits several months earlier in the drier and stressed sites in the Ayeyarwady delta area in Myanmar. For instance, *Aegiceras corniculatum* flowers and fruits during May to mid-July on the drier sites, but flowers and bear fruits only during July and mid-August in the lower intertidal zone. This general trend applies to most species that naturally occur over a wide range of sites (FAO, 1994).

Hong (1996) has reported from Vietnam that the seeds of *Avicennia* are semi-viviparous. Fully mature *Avicennia* propagules show the following characteristics: the colour of the seed coat changes from greenish to light yellowish, cracks can appear on the seed coat: fruit is easily removed from the parent tree. The seed of *Aegiceras* are also semi-viviparous. Ripe propagules can be recognised by the colour of the seed coat, which changes from pale yellow to brown. Similar observations were noticed in Goa and Middle Andaman during the course of present study (Table- 4.5).

CHAPTER-5

ARTIFICIAL REGENERATION OF MANGROVES

CHAPTER-5

ARTIFICIAL REGENERATION OF MANGROVES

5.1 INTRODUCTION

Primarily due to economic benefits associated with the mangroves, they were overexploited in the past, which resulted in degradation of mangroves. At several places mangroves are degrading mainly due to deforestation and reclamation (Untawale, 1984, 1987; Untawale and Wafar, 1985). This indiscriminate exploitation of mangroves by man has left them in varying degrees of degradation (FAO, 1994). As a result of indiscriminate deforestation and reclamation, some species no longer occur. (Untawale, 1984). Best examples of this are *Heritiera* and *Nypa* species. Both these genera were found along West Coast of India, as evidenced by the fossil records, but now they are presented only along the East Coast of India in Sunderbans, Andaman and Nicobar Islands, and Orissa. The reduction of mangrove cover has resulted in the dwindling of fisheries production along the West Coast. Estuaries on the West Coast are narrow, unlike those on the East Coast of India (Anandrao *et al.*, 1986; Anonymous, 1991; Jagtap *et al.*, 1994; Untawale *et al.*, 1982). In the last 12 to 13 years, Government of India and State Governments have taken very effective steps for conservation and development of mangroves (Anonymous, 1989). Not only Indian community but the world community has now realised the significance of mangroves (FAO, 1994). Today, most of the mangroves bearing countries in the world have their own mangrove management plans. Restoration of degraded mangrove areas through artificial regeneration form an important component of most of the mangrove management plans.

Degraded mangrove areas can be restocked either naturally or artificially. Vast stretches of intertidal mudflats are available in India for the restoration of mangroves (Anonymous, 1992). Success of natural regeneration varies from place to place and from species to species and it depends on various factors viz. production of abundant propagules and seeds, favourable site condition for germination cum establishment, degree of biotic interference and other abiotic factors. Taking some measures like removal of weeds, debris in the area and protection from livestock can further facilitate natural regeneration. Natural regeneration offers many advantages such as low cost of regeneration and also the area will have the same original vegetation with out changing the composition (Khanna, 1977).

Artificial regeneration has several advantages such as production of genetically superior stock, species selection as per choice and requirement, and above all, in most of the cases degraded, difficult and pest infested areas can be quickly restored through artificial regeneration (Field, 1996). The major objectives of artificial regeneration of mangroves are to check soil erosion; enhancement of natural regeneration in future; production of fuel, fodder and timber; effective utilisation of barren and unused land to increase area under mangroves to derive maximum direct and indirect benefits; beautification of area; improvement of habitat; to support fisheries, apiculture etc (FAO, 1994).

Plate-5.1 gives a view of man-made degraded mangrove area in Middle Andaman while Plate-5.2 shows successful artificial regeneration of mangroves in Middle Andaman for quick restoration of the degraded areas.

(Hong, 1994) reported as follows regarding reforested mangroves in Vietnam: "The rehabilitation of mangrove forests has resulted in certain changes in the physical properties of soil in some areas. The substrate has been gradually transferred into loam and the pH value increased which indicates a reduction in the soil acidity. There has been a steady increase in the litter production, resulting in the increase of commercially important species of fish, shrimps and other aquatic products. A change was also observed among the wildlife population including an abundance of some species of reptiles and avifauna. In addition, accretion has resulted in a gain of 340 ha of land and erosion of riverbanks has been reduced".

In Havana province (Cuba), both environmental and socio-economic effects of mangrove reforestation were clearly observed. They include the following: salinity was reduced in soils devoted to agriculture; erosion of coastline by marine action was reduced, marine and terrestrial fauna as well natural breeding niches increased; forestry products such as charcoal, timber, bark, honey and firewood increased; fires in mangrove areas decreased and unproductive marshes (at high risk of fire) acquired a productive potential (Padron, 1996).

PLATE- 5.1

A man-made degraded mangrove area in Middle Andaman

PLATE- 5.2

Successful artificial regeneration of mangroves in Middle Andaman for quick restoration of degraded mangrove areas

5.2 MATERIAL AND METHODS, RESULTS AND DISCUSSION

This chapter covers a number of sub-studies related to the artificial regeneration of mangrove. Therefore, for the sake of convenience and coherence, material and methods; results and discussions for a particular sub-study have been presented in continuation.

5.2.1 ESTABLISHMENT OF MANGROVE NURSERIES AND PLANTATIONS AND STUDY OF ITS TECHNIQUES

Material and methods

For the purpose of raising seedlings, conducting related studies and experiments, intertidal **mangrove nurseries** were established in Goa and Middle Andaman. In Goa, nurseries were established at Chorao, Colvale and Borim. In Middle Andaman one main nursery was established at Shyamkund and some more temporary nurseries were established at various places exclusively for experimental purposes. Following general methodology was adopted for raising mangrove nurseries.

Nursery sites were cleaned and leveled. All the weeds, grasses and other objectionable material were removed from the area. The area was fenced by using wooden poles and barbed wire for protection purposes. To raise seedlings of mangrove species in the nursery, perforated polybags of 5"×8" size were filled with sandy / silt clay collected from the area adjacent to nursery site and arranged in beds of convenient size. To provide support to these filled polybags, a framework made up of bamboo splinters was used along the boundary of the individual bed. Perforated polybags were used in the nursery so as to promote interaction of water inside and outside polybags. All the nursery works were done during low tide. Separate bed was made for each mangrove species.

Propagules were carefully inserted in the soil filled polythene bags. About one-fourth to one-fifth portion of the propagule was inserted in the soil. Deep insertion was not done.

Where seedlings were to be raised from seeds, the fruit/ seed were sown in the mother bed and transplanted the seedlings when they attained a height of 5-10 cms. The fruit of aviparous mangrove species contain a well-developed seed(s) inside. Fruits automatically burst on maturity releasing the seeds. Fruit/ seed were placed about 12mm deep in the soil. After transplantation of seedlings in the polythene bags, these were protected against biotic interference and weeds were periodically removed from the nursery. Failed polybag seedlings were removed from the bed and replaced by another polybag seedling of the same age so as to have seedlings of same age in one bed. Seedlings were kept for one year in the nursery.

As far as **site selection for mangrove plantation** is concerned, only those sites were selected for the planting where soil substratum was stable and presence of some grasses and other vegetation was noticed. Moreover, sheltered sites were selected so as to protect the seedlings against waves and water current action.

Little **site preparations** were required for mangrove plantations. However, following site preparation works were taken up, wherever necessary. Weeds and debris were removed from the planting site. Big plantation patches were divided into smaller blocks with suitable inspection paths. Protection of planting site was ensured.

Naturally germinating / established species were studied in a particular locality to get an idea about the **suitability of species**. While planting natural zonation pattern was followed. Salinity of water was also studied to select appropriate species capable of surviving in a particular salinity zone.

Seedlings were planted in intertidal zone where they were inundated by water regularly. Taller seedlings like *Rhizophora, Kandelia* etc. were planted towards waterfront and smaller ones behind it.

Planting of mangroves was be broadly divided into two categories i.e. planting of propagules producing mangroves and planting of non-propagules producing mangroves. In case of propagules producing mangrove species like *Rhizophpra,* *Ceriops*, *Bruguiera* and *Kandelia*, propagules were collected without damaging the radicle for direct planting.

Spacing in the plantation was decided on various parameter viz. species, pre-existing vegetation on the planting site, expected survival rate etc. For example spacing was more in the case of planting of bigger tree species like *Rhizophora mucronata*. Spacing was less in case of small tree species like *Kandelia candel*. The spacing varied from 30 cms × 30 cms to 1m × 1m. To ensure best results the propagules were planted at the earliest after collection. After planting no special care was given to the plantations except protection from the biotic interference. Seedlings of some mangroves like *Avicennia* and *Sonneratia* do not produce propagules but they produce fruits. Seedlings of these species were raised and maintained in the nursery till they attained the age of one year. In Goa, these nursery seedlings were used for plantation when the propagules of mangrove species were not available. The seedlings were transported from nursery site to the planting site by boat. While transportation care was taken to avoid damage/ disturbance to the root system. Before planting the mangrove seedlings in the pit of appropriate size, the polythene bags were removed carefully by using sharp blade/ knife so as to cause minimum disturbance to the root system.

Results

Table-5.1 shows details of mangrove plantations in Goa. Around 450 ha plantations were raised under my overall supervision and close association during the years 1992-1997. In addition to this, about 5 ha area in Middle Andaman was brought under mangrove cover as experimental plantations during 1997-1999.

TABLE-5.1

MANGROVE PLANTATIONS IN GOA

Year of planting	Locality	Total area (ha)	Species used in planting
1985-86	Chorao Island	75.00	*Rhizophora mucronata, Rhizophora apiculata and Avicennia officinalis*
1986-87	Chorao Island	20.50	-do-
1987-88	Chorao Island	56.00	-do-
1988-89	Diwar Island, Piedade, Cumbarjua, Madel	48.75	-do-
1989-90	Varando, Ekoshi	54.75	-do-
1990-91	Ekoshi, Patto, Rua de Quram	26.50	-do-
1991-92	a) 26 ha. at Madkai along Zuari estuary b) 24 ha. along Mapusa estuary	50.00	*Rhizophora mucronata, Rhizophora apiculata, Avicennia officinalis, Avicennia marina, Bruguiera gymnorrhiza, Kandelia candel*
1992-93	a)30 ha along Zuari estuary between Borim and Shiroda b) 55 ha. along Cambarjua canal c) 85 ha. along Mapusa estuary	150.00	-do-
1993-94	a) 35 ha. along Mandovi / Mapusa estuary b) 65 ha. along Zuari estuary	100.00	-do-
1994-95	a) 50 ha. along Terekhol estuary b) 100 ha. along Zuari estuary	150.00	-do-
1995-96	Along Mandovi, Zuari and Terekhol estuaries	146.50	-do-
1996-97	a) 26.5 ha along Terekhol estuary b) 21.5 ha Shiroda, Panchvadi, along Zuari estuary	48.45	-do-
	Total	926.45	

SOURCE: Govt. of Goa, Forest Department, Research and Utilization Division.

Discussion

It is necessary to conduct experiments on the artificial regeneration of mangroves in order to determine the best method of raising various species and the conditions required for then regeneration (Qureshi, 1957).

Techniques adopted for mangrove nurseries and plantations play most significant role in success or failure of the work. Lot of work has been done by various workers in the field of artificial regeneration of mangroves. There are several detailed description of nursery practices such as Qureshi, (1990), Untawale, (1993) and Siddiqi *et al.*, (1995). For any large-scale reforestation or restoration programme, nurseries are essential (Untawale, 1993).

Artificial regeneration of many mangrove species necessarily involves raising of **mangrove nursery**, which can serve many **objectives**. A mangrove nursery is raised to grow seedlings of those mangrove species whose propagules or seeds cannot be planted directly for successful regeneration. Generally, mangrove species with long propagules like *Rhizophora mucronata, R. apiculata, Ceriops tagal, Bruguiera gymnorrhiza* and *Kandelia candel* are taken for direct planting. This is because long propagules are physically better suited to withstand the impact of a wider range of tidal inundation (Soemodihardjo and Sumardjani, 1994). In heavily crab infested areas or areas prone to deep flooding, it may be advantageous to raise the seedlings in a nursery prior to planting in the field (FAO, 1994). For other species such as *Sonneratia* spp, *Avicennia* spp, and *Excoecaria agallocha*, which have relatively small seeds, raising of seedlings in a nursery is advisable (Siddiqi *et al.*, 1993). Species, which produce small sized propagules, are also chosen for raising seedlings in the nursery for better plantation results. Nursery can be used for raising tall seedlings to meet special objectives. For example, in Barnacle (cone shaped shell animal) infested area, it is better to plant tall seedlings so that growing shoots of tall seedlings remain above the level of high tide. Barnacle cannot attack the portions above water level. Nursery can be used for multiplication of rare mangrove species. Seeds or propagules of rare and endangered species can be collected and multiplied in the nursery under intensive care for eventually planting out the seedlings. For example, *Ceriops tagal* is found in Goa at Keri only along Terekhol Estuary. This species can be multiplied in the nursery to save it from extinction. Mangrove nursery can be established near a city or town or village to educate the students and others for spreading the awareness regarding significance of mangroves. A mangrove nursery can be established for conducting research experiments.

Mangrove propagules used for direct planting are not available throughout the year. Therefore, nursery stock can be used for plantation when propagules are not available naturally. A nursery can function as a temporary storage for propagules or seeds, which are abundantly available during the peak season and can culture them as young plants for use as required. Nurseries can be very beneficial in that they provide young plants that are more resistant to pests (Soemodihardjo *et al.*, 1996).

Untawale, (1996) reported that **location of mangrove nursery** should preferably be near the estuary in the low-lying areas of the sea, which gets inundated during the high tide. This type of location ensures automatic watering of the mangrove seedlings twice a day during the high tide. The site should be close to the planting site as for as possible so as to minimise the cost of transportation of seedlings from nursery to the planting site. A nursery is normally established on a sheltered site that is inundated by spring tides (Field, 1996). It may not be possible to raise the entire mangrove species in one area as the salinity of water varies from place to place and different species grow in different salinity regime. Therefore, more than one nursery may be established in order to cover maximum species in the nurseries. Nursery grown seedlings generally show higher success rate than propagules (Saenger, 1996).

The salinity of the soil water has long been recognised as an important factor in regulating growth, height, survival and zonation of mangroves (Macnae, 1968; Semeniuk, 1983). *Avicennia marina* is a pioneering mangrove species and is the most tolerant of extremely saline conditions. Maximum salinity tolerance for *Avicennia marina* is 90 ppt compared to between 55 and 60 ppt for *Rhizophora mucronata* and *Ceriops tagal* (Qureshi, 1996).

The nursery site may be such that where it is naturally protected from biotic interference otherwise artificial protection proves costly. If the nursery is set up for the educational and awareness purposes, it should be easily accessible preferably through a road so that people may easily and conveniently visit it.

The **choice of mangrove species** for a given site is of vital importance. Plantation's success depends critically on the species planted, as they have different site requirements. An optional level of tidal inundation and degree of salinity are important factors leading to survival and development of planted seedlings (Siddiqi & Khan, 1990). Besides, some species grow well on new accretions, while others do well on relatively matured soils (Das and Siddiqi, 1985). Light is also an important factor determining successful establishment of plantations (Saenger, 1986). Usually, pioneer species such as *Sonneratia apetala* and *Avicennia officinalis* are strongly light demanding, but species appearing at some later stages are either shade bearers initially or throughout their life cycle (Troup, 1921; Ali, 1974).

Natural mangrove species present in the vicinity of the planting site also guide us regarding the suitability of the particular mangrove species on a particular site. At the same time we should go for detailed study of the planting site and if it is found that site is suitable for the introduction of a new species which is not pre existing in the area, it may be taken up for planting. This will ensure enrichment of mangrove plantation with different species. It is always better to introduce a new species in a smaller area to watch its performance so as to avoid financial loss, in case of failure due to some unforeseen factor.

During fruiting season mature and healthy propagules, seeds and fruits should be collected for planting. Malformed propagules should be discarded. Newly fallen mature propagules can be retrieved from the forest floor at ebb tide. The older fallen propagules are often damaged due to attack by insects. Insect damage can be recognised by the presence of borer holes in the hypocotyl (Chan, 1994; Agaloos, 1994).

Seeds and propagules collection from the plants is better as the seed selection is possible in this case. Seeds and propagules should be collected from superior trees (Plus trees) which can be marked for annual collection of seeds. A plus tree is a healthy middle aged tree with well-developed crown showing vigorous growth and producing large number of healthy fruits. If possible, Seed Stands should be developed having large number of plus trees in a small compact area. If practically possible, all inferior trees should be removed from such areas to avoid cross-pollination with inferior trees.

Some mangrove species, such as *Rhizophora mucronata*, can bear fruits at the age of 3-4 years (Chan 1994). In this respect Wirjodarmodjo and Zufri Hamzah (1984) suggested that the seeds of *Rhizophora* should be collected from mother trees that are atleast five years old. According to Mulia (1993) the best mother trees for *Bruguiera gymnorrhiza* are those aged 8-10 years, although this species may start producing fruits at the age of 3 years.

The seeds are also collected by climbing healthy trees. Fallen *Avicennia officinalis* fruits are usually collected from around the base of mother trees (Siddiqi *et al.*, 1993). Seeds should be utilised at the earliest after collection for good results. The viability of seeds declines quite fast. No seed was found to germinate when sown 60 days after fruit collection (Siddiqi & Islam, 1988).

While undertaking **transportation of Seeds, Fruits and Propagules,** care must be taken to preserve their viability. For the purpose of transportation, propagules of *Rhizophora*, *Kandelia* may be kept in bundle form in horizontal position. Propagules should be kept in wet condition and may be covered with a wet jute cloth or wet grasses. Care should also be taken that the plumule is not broken or damaged during the transportation (Hong 1996). Retaining the pericarp in place to provide protection for rudimentary shoot of the seed is also necessary (Agaloos, 1994). Propagules should also be exposed to moderate sunlight to prevent fungal attack. Near the planting site propagules may be kept in the natural saline water in a sheltered place. Seeds/ fruits of *Avicennia*, *Sonneratia* etc. should be collected in gunny bag or bamboo basket and should be kept in shade. Mangrove communities are strongly influenced by the extent of fresh water influence either from rainfall or from river discharge (Bunt *et al.,* 1982). Planting of mangroves is skilled work because the job has to be completed during low tides, when the intertidal area is exposed. Moreover, this is a slushy area where conditions are difficult and specialised pre-planned plantation techniques are required.

Spacing of the seedlings or planting stock is of critical importance to the economics and ultimate success of the restoration process. In terms of cost, a decrease in the spacing by one-third doubles the number of plants needed (Lewis, 1982). The determination of the proper spacing intervals should be based on the distance that will minimise early competition. The recommended spacing for propagules or seedlings in 0.6 to 1.2 m for *Rhizophora* species and 1.5 m for *Avicennia* species (Hamilton and Snedaker, 1984). For *Sonneratia apetala* spacing of 1.5 m x 1.5 m was adopted (Siddiqi & Khan 1996). The high density of seedlings appears to give protection from the sun, wind and tide whilst the seedlings are taking root. Over a period of time the strongest ones survive and the mature trees are more evenly spaced (Qureshi, 1996).

During the course of present study, closely spaced plantatons were seen in a better condition. The spacing or density of the planting stock is of fundamental importance. Whereas dense plantings result in slower growth due to competition and escalate the restoration cost, they also result is earlier canopy closure, a highly desirable end point. At some later time, the plant population can be reduced by thinning to the desired final density.

Before any mangrove planting, it is essential to know the salinity, tidal regime and the currents in the particular site (Untawale, 1993). Appearance of grasses (*Porteresia coarctata* and *Myrostachya wightiana)* show that the site is relatively stable and protected from severe wave action. Planting should be undertaken on such sites (Siddiqi and Khan, 1995).

Direct planting of propagules or seedlings is the most widely followed practice since it is considered to be the most successful option (Lewis, 1982; Getter *et al.*, 1984). In this regard, it has been generally established that the performance and success of establishment of mangrove propagules is proportional to their size

(Deshmukh and Karmarkar, 1990). Propagules of *Rhizophora mangle* are planted by inserting them gently into the sediment so that they will not fall over (only 4 to 7 cms.); a deeper planting depth is not recommended (Hamilton and Snedaker, 1984).

In almost all the countries direct planting using freshly collected propagules and indirectly planting using nursery stock/ wildings of those spp which have small propagules seeds have been adopted (Soemodihardjo *el al.,* 1996). In Goa direct planting of *Kandelia candel* and in Middle Andaman direct planting of *Ceriops tagal* were very successful.

In Indonesia, nursery seedlings were planted for *Bruguiera gymnorrhiza* and *Ceriops tagal* since the species has a short propagule and is susceptible to physical damage, particularly at places with deep tidal flooding (Soemodihardjo *et al.*, 1996). However, in Middle Andaman *Ceriops tagal* and *Bruguiera gymnorrhiza* have been successfully planted in the middle inter -tidal zone using direct planting technique. Indirect planting can be useful in solving some other specific problems. Some planted sites at Tembilahan (Indonesia) were susceptible to pest attack by long tailed macaques (*Macaca fascicularis*) and crabs (*Sesarma* spp). These animals usually attack the newly planted propagules. To overcome this problem, restoration of such places was mostly executed through indirect planting. Experience has shown that macaques and crabs rarely disturb young mangrove plants (Soemodihardjo *et al.*, 1996).

In most of the places, area available for planting on both the banks of the estuaries in Goa is marked by two conspicuous zones with their boundary running along the estuary. First zone is that which is away from the center of the river and characterised by the presence of pneumatophores, grasses etc. The second zone is closer to the center of the river / estuary and devoid of any vegetation. It is only deposition of sandy / silt clay on the banks.

Planting of mangroves was tried in both these zones and it was observed that survival percentage in the first zone was 80% or more while in the second zone survival percentage varied from 5-10% (Kumar, 1995). In the first zone pneumatophores and / or grasses bind the soil particles together and reduce the resultant impact of wave action on individual young propagules/ seedlings thereby help the young seedlings in their establishment. In the second zone soil is loose and wave action is much stronger as compared to first zone, therefore, young seedlings of mangrove do not get proper environment for their establishment. Based on our experiences it was decided to take up planting work in the first zone only.

On the basis of overall results, plantation of mangrove species in Goa can be graded as very successful. In the beginning years the survival percentage in the plantation was low (around 50% or less) mainly due to extensive fishing activities which are very common along the rivers and estuaries (Kumar, 1995). Use of drag fishing net caused maximum damage to the young seedlings.

As far as **maintenance of the plantations** is concerned, only protection and causality replacements were done both in Goa and Andamans. *Acrostichum aureum* was not a threat to mangrove plantation in these two areas but it was observed that *A. aureum* was growing very rapidly in fallow lands and extending day by day. If no steps are taken now to contain *Acrostichum aureum* it may be a serious problem in future especially in South Andaman including areas adjoining Port Blair. The tending of mangroves requires less efforts and funds when compared to tending terrestrial plants (Hong 1996). Weeding in one year old plantation is done twice in Vietnam and a patching operation is done in the first year (Htay, 1994). In Indonesia, weeding was carried out periodically until the plantation was 5 years old and *Acrostichum* clearing had to be done twice a year (Soemnodihardjo and Sumardjani, 1994).

Cost Analysis of Mangrove plantations is an important component of project report. Majority of the plantation works were undertaken by using direct planting method, which involves planting of propagules of various mangrove species. This method is much cheaper than the planting of non-propagule producing species, which involves raising of the nursery and then planting out one-year-old seedlings. Raising of mangrove nursery and plantation are labour oriented works. Therefore cost of these works is largely affected by wages rate prevailing in an area. In Goa, these works were done as per the estimates shown in Table- 5.2 & 5.3 that are based on the wages rate of Rs. 29 per person per day. The development of nurseries, collection and transportation of planting materials and planting of mangroves in the intertidal mudflats are labour-intensive and the cost varies from place to place. The cost of mangrove nursery depends on the area, design and the facilities needed. Currently the planting cost in Goa varies from 2000 rupees to 3,500 rupees per ha (Untawale, 1996).

Plates- 5.3 & 5.4 show *Rhizophora apiculata* plantations in Middle Andaman and Chorao (Goa) respectively. Plates- 5.5 and 5.6 give a view of plantations of *Ceriops tagal* and *Bruguiera gymnorrhiza* respectively in Middle Andaman.

TABLE-5.2

COST OF RAISING MANGROVE SEEDLINGS IN THE NURSERY

S.N.	Particulars of Works	Maximum average cost of one polybag seedling (Rs.)
1.	Site and bed preparation, filling of polythene bag and arranging in the bed.	0.40
2.	Cost of seed collection, its sowing in the polythene bag, maintenance works and miscellaneous charges.	0.10
3.	Cost of polythene bag of 5"×8" size (200 gauge)	0.20
	Total	**0.70**

Source: Kumar (1995)

TABLE-5.3

COST OF RAISING MANGROVE PLANTATIONS BY USING DIRECT PLANTING METHOD

S.N.	Particulars of works	Maximum average cost of raising one hectare plantation (Rs.)
1.	Survey and demarcation of the area	100.00
2.	Collection of propagules and transportation charges	600.00
3.	Planting work and other miscellaneous charges	1000.00
	Total	**1700.00**

Source: Kumar (1995)

PLATE- 5.3

Plantation of *Rhizophora apiculata* in Middle Andaman

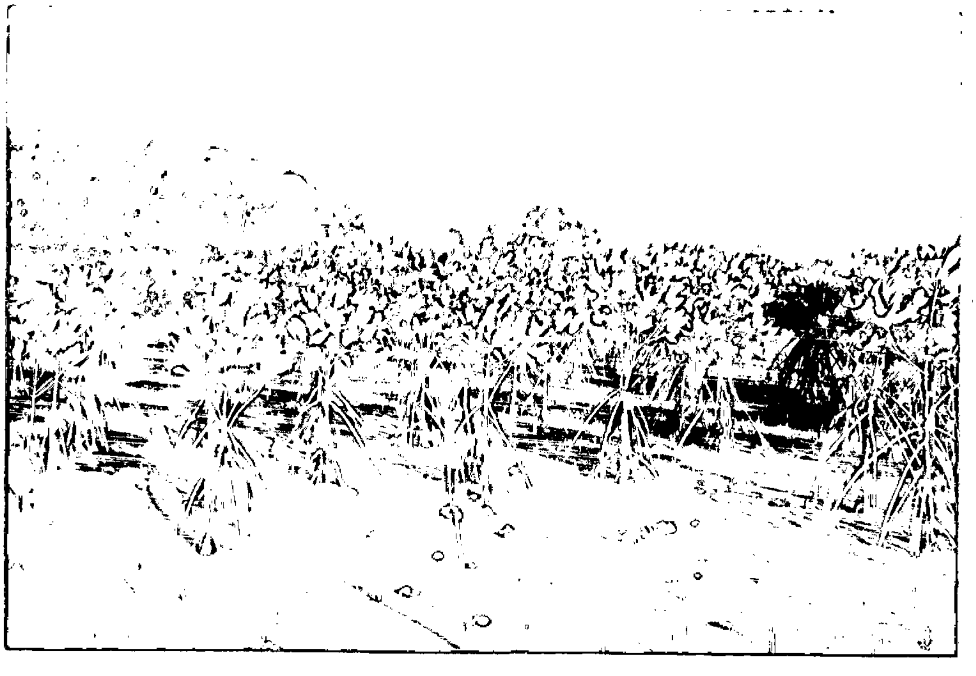


PLATE- 5.4

A well-established plantation of *Rhizophora apiculata* at Chorao (Goa)

PLATE- 5.5

Plantation of *Ceriops tagal* in Middle Andaman

PLATE- 5.6

Plantation of *Bruguiera gymnorrhiza* in Middle Andaman

5.2.2 SURVIVAL PERCENTAGE AND GROWTH PERFORMANCE OF ONE YEAR OLD MANGROVE SEEDLINGS IN NURSERIES OF GOA AND MIDDLE ANDAMAN

Material and methods

The study was conducted in various mangrove nurseries of Goa and Middle Andaman in order to collect information on maximum number of species. The nurseries were located in the natural habitat of the species in respect of whom, the study was carried out. Except nursery at Chorao (Goa), all other nurseries were temporary, which were established with some specific objective, like experimental studies, plantation in nearby area etc.

Although in many nurseries, lakhs of mangrove seedlings were raised but for the purpose of this study, one bed of each species containing 1000 numbers of seedlings was earmarked for collection of data. During the entire study, it was ensured in the nursery that all the beds, whether experimental or not, get the same treatment and the experimental saplings should be representative of all the seedlings in the nursery. Age of the seedlings was calculated from the date of transplanting seedlings in the polythene bags. At the end of one- year number of survived seedlings were counted to calculate survival percentage. Heights of 100 seedlings of each species, which were randomly selected from these experimental beds, were recorded to calculate average height of one-year-old nursery seedlings.

Results

Results of the study are shown in the Table-5.4. There are three species namely *Rhizophora mucronata, R. apiculata* and *Bruguiera gymnorrhiza* whose study was conducted both at Goa and Middle Andaman. Four species namely *Bruguiera parviflora, Ceriops tagal, Xylocarpus granatum* and *Nypa fruticans* are not found naturally in Goa. Therefore, these species were exclusively studied in Middle Andaman. Average height of seedlings varies from species to species as observed during the study. Results have been discussed in subsequent part of this chapter.

TABLE-5.4

SURVIVAL PERCENTAGE AND GROWTH PERFORMANCE IN ONE YEAR OLD MANGROVE SEEDLINGS IN NURSERIES OF GOA AND MIDDLE ANDAMAN

S.N.	Species	Location of Nursery	Survival %	Average height (meters)
1	*Rhizophora mucronata*	(i) Chorao (Mandovi Estuary), Goa (ii) Shyamkund, Middle Andaman	98% 100%	0.83 0.85
2	*Rhizophora apiculata*	(i) Chorao, Goa (ii) Shyamkund, Middle Andaman	95% 99%	0.67 0.69
3	*Avicennia officinalis*	Borim (Zuari Estuary), Goa	94%	0.40
4	*Avicennia marina*	-do-	90%	0.54
5	*Sonneratia alba*	-do-	76%	0.14
6	*Sonneratia caseolaris*	Colvale (Chapora Estuary), Goa	85%	0.14
7	*Kandelia candel*	-do-	88%	0.68
8.	*Bruguiera gymnorrhiza*	(i) Borim, Goa (ii) Shyamkund, Middle Andaman	60% 84%	0.46 0.49
9	*Bruguiera parviflora*	Yerrata, Middle Andaman	26%	0.30
10	*Ceriops tagal*	-do-	96%	0.52
11	*Xylocarpus granatum*	-do-	41%	0.25
12	*Nypa fruticans*	Dhaninallah, Middle Andaman	30%	0.22
13	*Aegiceras corniculatum*	Uttara, Middle Andaman	34%	0.19

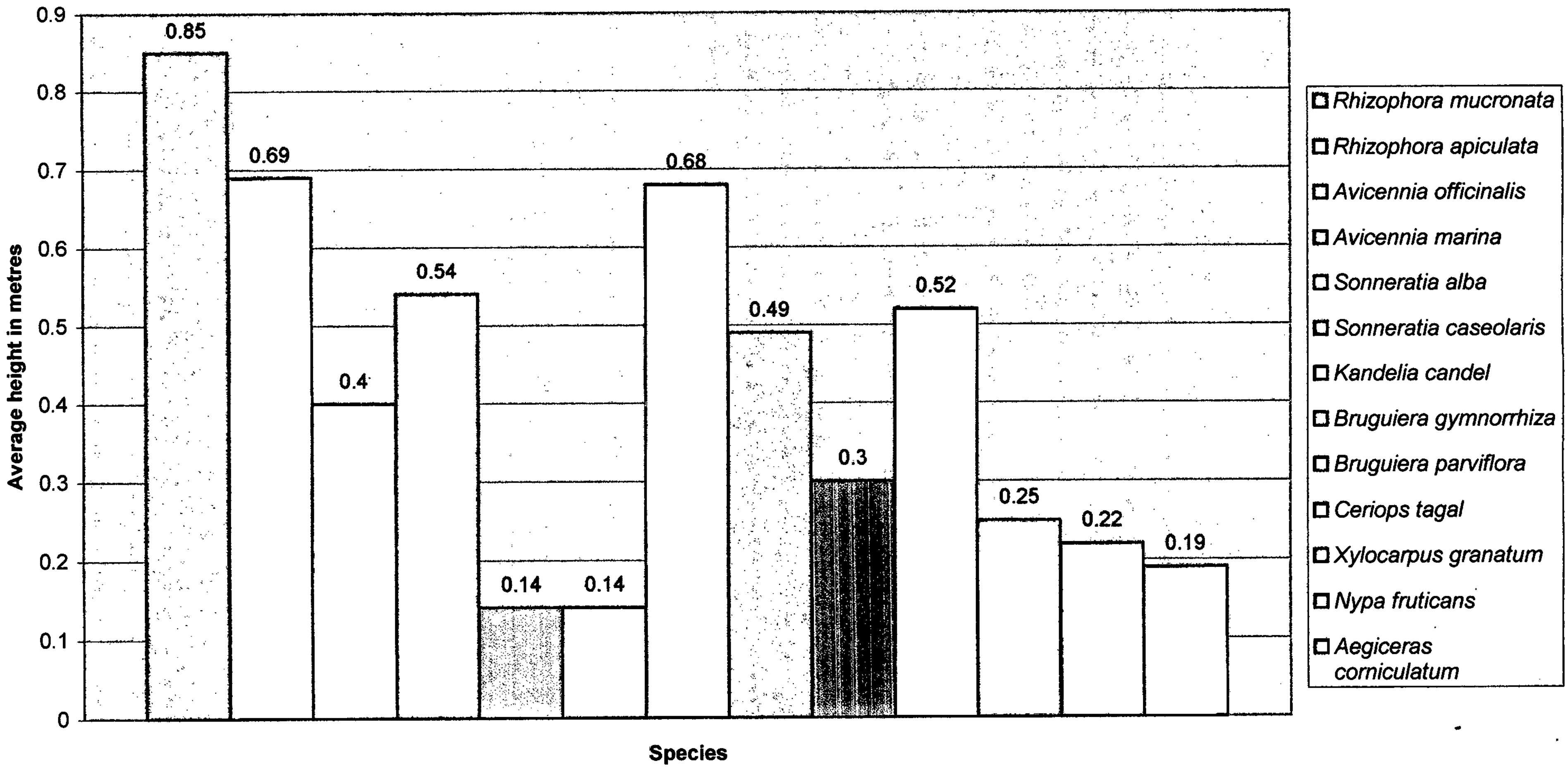
Discussion

Survival percentage of *Rhizophora mucronata* and *R. apiculata* saplings was studied in the nurseries of Goa and Middle Andaman and found very high survival percentage ranging from 95% to 100%. This shows that the nursery techniques followed for these species are appropriate and can be taken as standard techniques. Siddiqi *et al.*, (1993) reported 100% germination of *Rhizophora* species in mangrove nursery in Bangladesh. *Avicennia officinalis* and *A. marina* also showed very high survival percentage (94% and 90%) respectively. Results obtained on *Sonneratia alba, S. caseolaris* and *Kandelia candel* with survival percentage of 90%, 76%, 88% respectively can also be classified as satisfactory. *Bruguiera gymnorrhiza* and *Ceriops tagal* seedlings also showed very good results in Middle Andaman with 84% and 96% of survival respectively but in Goa, *Bruguiera gymnorrhiza* showed only 60% survival. Therefore, there is a need to study growth of *Bruguiera gymnorrhiza* seedlings in nursery to upgrade the techniques with reference to factors of locality prevailing in Goa. It is pertinent to point out that Goa has only limited plants of *Bruguiera gymnorrhiza,* which are generally small or medium sized. At the same time Middle Andaman has large number of *Bruguiera gymnorrhiza* plants with plenty of full-grown trees ranging in height from 25 to 35 meters (personal observation).

Bruguiera parviflora and *Avicennia corniculatum* seedlings raised in the nurseries showed a low survival percentage of 26% to 34% respectively. This may be attributed to small size of their propagules. It has been observed that, in general, species with small propagules show lower survival percentage. Smaller propagules are more susceptible to various climatic, edafic and biotic factors (Soemodihardjo *et al.*, 1996). *Xylocarpus granatum* and *Nypa fruticans* seedlings also showed lower survival at 41% and 30% respectively. At a younger stage, attack by crabs was noticed who feed on kernel portion of the seeds and young tissue of the growing seedlings. 60-65% germination in respect of *Xylocarpus granatum* and 95% germination in respect on *Nypa fruticans* have been reported from Bangladesh (Siddiqi *et al.*, 1993).

Average heights of one-year old nursery seedlings of various species at different locations have been shown in Figure-5.1. Maximum height was noticed in *Rhizophora mucronata,* which can be attributed to its biggest size of propagule among mangrove species. Slowest height growth was observed in *Sonneratia alba* and *S. caseolaris* with height of 0.14 metre each at the age of one year. Siddiqi *et al.*, (1993) reported heights of 10-month old *Rhizophora mucronata* and *Sonneratia caseolaris* as 100-125 cms and 70-90 cms respectively. Inherent characteristics of plants and various environmental factors are responsible for different rate of growth in different mangrove species.

Figure-5.1 Height of one year old mangrove seedlings in nursery



5.2.3 SURVIVAL PERCENTAGE OF MANGROVE SPECIES IN EXPERIMENTAL PLANTATIONS OF GOA AND MIDDLE ANDAMAN

Material and methods

The study was conducted in respect of *Rhizophora mucronata, R. apiculata, Avicennia officinalis, Kandelia candel, Bruguiera gymnorrhiza, Bruguiera parviflora* and *Ceriops tagal.* In case of *Avicennia officinalis* and *Bruguiera parviflora* one-year-old polythene bag seedlings were used and in case of remaining species propagules were directed planted in the experimental plantations. Sites of the plantation were selected in natural habitat of respective species. Experimental planting was carried out in 0.25 hectare at spacing of 0.50×0.50 metres. Thus, total 10,000 seedlings of each species were planted in different plots. After plantation, areas were protected from biotic interference. Survival percentage was recorded up to maximum three years at an interval of one year.

Results

Results obtained on survival percentage of mangroves in experimental plantations of Goa and Middle Andaman are shown in the Table-5.5. It can be seen from the table that the survival percentage goes down with the passage of time and by the end of third year survival varies from 48% to 76%.

TABLE-5.5

SURVIVAL PERCENTAGE OF MANGROVES IN EXPERIMENTAL PLANTATIONS OF GOA AND MIDDLE ANDAMAN

S. N.	Species	Location	Survival % against the age of plantation		
			1 Year	2 Year	3 Year
1.	*Rhizophora mucronata*	(i) Borim, Goa	73	60	55
		(ii) Yerrata, Middle Andaman	86	75	-
2.	*Rhizophora apiculata*	(i) Galgibag, Goa	69	56	48
		(ii) Yerrata, Middle Andaman	92	78	-
3.	*Avicennia officinalis*	Borim, Goa	84	76	70
4.	*Kandelia candel*	Shiroda, Goa	90	81	76
5.	*Bruguiera gymnorrhiza*	Yerrata, Middle Andaman	88	78	-
6.	*Bruguiera parviflora*	Yerrata, Middle Andaman	63	-	-
7.	*Ceriops tagal*	Yerrata, Middle Andaman	95	86	-

Discussion

Mangrove planting appears easy but results in Vietnam show that the survival rate can be very low, if the right techniques are not applied (Hong, 1996). During 1978-89, total 29.583 ha of *Rhizophora apiculata* were planted at Can Gio and checking in 1990 revealed that only 18.125 ha were covered with mangroves. Nam *et al.*, (1992) reported 75% survival rate in one-year-old plantation of *Rhizophora apiculata.*

During the course of my prolonged field experience, it was noticed that closely spaced planting in mangroves gives better survival results. Stable and sheltered plantation sites also show better survival percentage. If the area is devoid of grasses, pneumatophores or other vegetation then closed spacing planting must be adopted. However, where grasses etc. are pre existing in the area, the spacing can be increased upto 1m × 1m or even 2m × 2m depending on the site conditions. It was also observed that by the end of the third year 25 to 50% mortality takes place in the plantation. If we go for close spacing planting, we may not need casualty replacement as the area will be well stocked with surviving seedlings. If the survival percentage remain high (around 80-90%) at the end of third year, many seedlings automatically die due to congestion as observed in some old plantation at Shyamkund in Middle Andaman. When plenty of mangrove propagules are available near the planting site, there should not be any hesitation for close space planting, as it is cost effective and gives good results. However, where polybags seedlings are to used for planting, appropriate decision has to be taken on spacing considering site condition and financial considerations as transportation and planting of polythene bag seedlings require much higher expenditure as compared to direct planting using propagules.

For the best result close space planting with thinning at various stages can result in best development of mangrove forests (Hong 1996). In Can Gio (Vietnam), by planting a large number of propagules, a very dense plantation is developed which can occupy the entire site at a very early stage. Because of the high density of trees in these plantations, thinning is important in order to ensure optimum forestry production. In most cases, the first thinning is conducted around 5th year of plantation establishment, when upto 25% of the trees are removed (Hong 1996).

In Can Gio District, the thinning regime, developed for *Rhizophora apiculata* plantations, is as follows:

The first thinning is carried out at 6 to7 years of age. The second thinning is carried out in plantations of 9 to 10 years of age leaving behind a residual stand of trees with a mean distance of 1.3 to 1.4m. A third thinning is proposed when the plantations reach 15 years of age and is essentially aimed at inducing natural regeneration prior to final felling at 20 years. The resultant mean inter-tree distance should be 2.0 to 2.5 m or about 1,600 to 2,500 trees/ha. A yield of 23 to 26 m3/ha by thinning (9 to 10 cms. dbh) is envisaged (Chan 1990). Can Gio has succeeded in restoring mangroves on the large area sprayed by herbicides and 18,800 ha of *Rhizophora apiculata* and 1031 ha of *Nypa* palm have been grown (Hong 1996).

In some rehabilitation areas of Indonesia, there are mangrove seedlings with a high density. At places where the density was greater than 5,000 seedlings per ha, a thinning process was carried out. This process was necessary to give the young plants more space to grow normally. Thinning is done in Indonesia in the plantation of 15 to 20 years of age having more than 1,100 trees per ha (Soemodihardjo *et al.*, 1996).

As regards the survival rate of the Tembilahan mangrove plantation, Sumardjani and Mulia (1994) provided following report: Indirect planting 85%; Direct planting with shade- 70%; Direct planting without shade-55%. The low survival rate of the unshaded direct planting is presumed to be due to attack by crabs and macaques as well as damage caused by direct sunlight. In India, Mangrove restoration programmes were initiated for the first time during 1985. Initial survival rate of seedlings ranged from 80 to 90%. However, due to biotic and abiotic factors, some areas showed only a 50% success (Untawale, 1996).

Plate-5.7 shows an experimental plot for restoration of highly degraded mangrove area through plantation at Yerrata (Middle Andaman). Plate-5.8 gives a view of close space planting of mangroves in Middle Andaman.

PLATE- 5.7

Experimental plot for restoration of highly degraded mangrove area at Yerrata, Middle Andaman

PLATE- 5.8

A view of close-space planting of mangrove in Middle Andaman

5.2.4 GROWTH PERFORMANCE OF *Rhizophora apiculata, R. mucronata* AND *Avicennia officinalis, A. marina* PLANTATIONS IN GOA

Material and methods

Mangrove plantations of various species are being raised in Goa since 1985-86. One locality was selected from plantations of different years to study growth performance of *Rhizophora apiculata* and *R. mucronata* up to the age of 12 years. All these plantations were raised by direct planting of propagules. In each of these localities 100 numbers of representative plants were selected and their height were recorded to calculate average height. Similarly, growth performance of *Avicennia officinalis* and *A. marina* was studied in each year plantations from 1991-92 to 1996-97. In case of *Avicennia,* one year old nursery seedlings were used for plantations. Therefore, average height of seedlings at the time of planting was recorded against one-year age of the seedlings in the plantation.

Results

Results obtained on growth performance of *Rhizophora apiculata, R. mucronata* and *Avicennia officinalis, A. marina* are depicted in Figure-5.2 & Figure-5.3 respectively. Figure-5.2 shows comparative growth of *Rhizophora apiculata & R. mucronata* while Figure-5.3 shows comparative growth of *Avicennia officinalis* and *A. marina. Rhizophora mucronata* shows little faster growth compared to *Rhizophora apiculata*. Similarly, *Avicennia marina* shows faster growth than *A. officinalis*.

Discussion

Rhizophora mucronata shows slightly better growth rate than *R. apiculata* (Figure-5.2). Mangrove reforestation at Pattani Province (Thailand) with *Rhizophora apiculata* gave good results. The average height of the 5 to 18 years old plantation varies from 3.56 to 14.09 m (Aksornkoae, 1996). In 1989, an inventory was carried out in Vietnam to investigate the growth of 14 years old *Rhizophora apiculata* plantations at different sites. Generally, the mean annual increment of diameter at breast height was 0.61 cm and height was 0.81m respectively, but it may very with the soil and level of inundation (Hong 1996). Wechakit (1987) gave figures on the growth and yield of *Rhizophora apiculata* plantations of different ages. The average height of the 3 to 15 year old plantations varied from 1.76m to 12.36 m.

Avicennia marina takes the lead in height growth right from the first year. In the third year *Avicennia marina* shows sharp increase in height increment as compared to *A. officinalis* but at the end of sixth year both the species reach to almost same height (Figure-5.3). At the Brisbane airport site (Australia) mean height of *Avicennia marina* was 1.8m after 12 years of growth (Saenger, 1996).

Figure-5.2 Growth performance of mangroves in plantations of Goa.

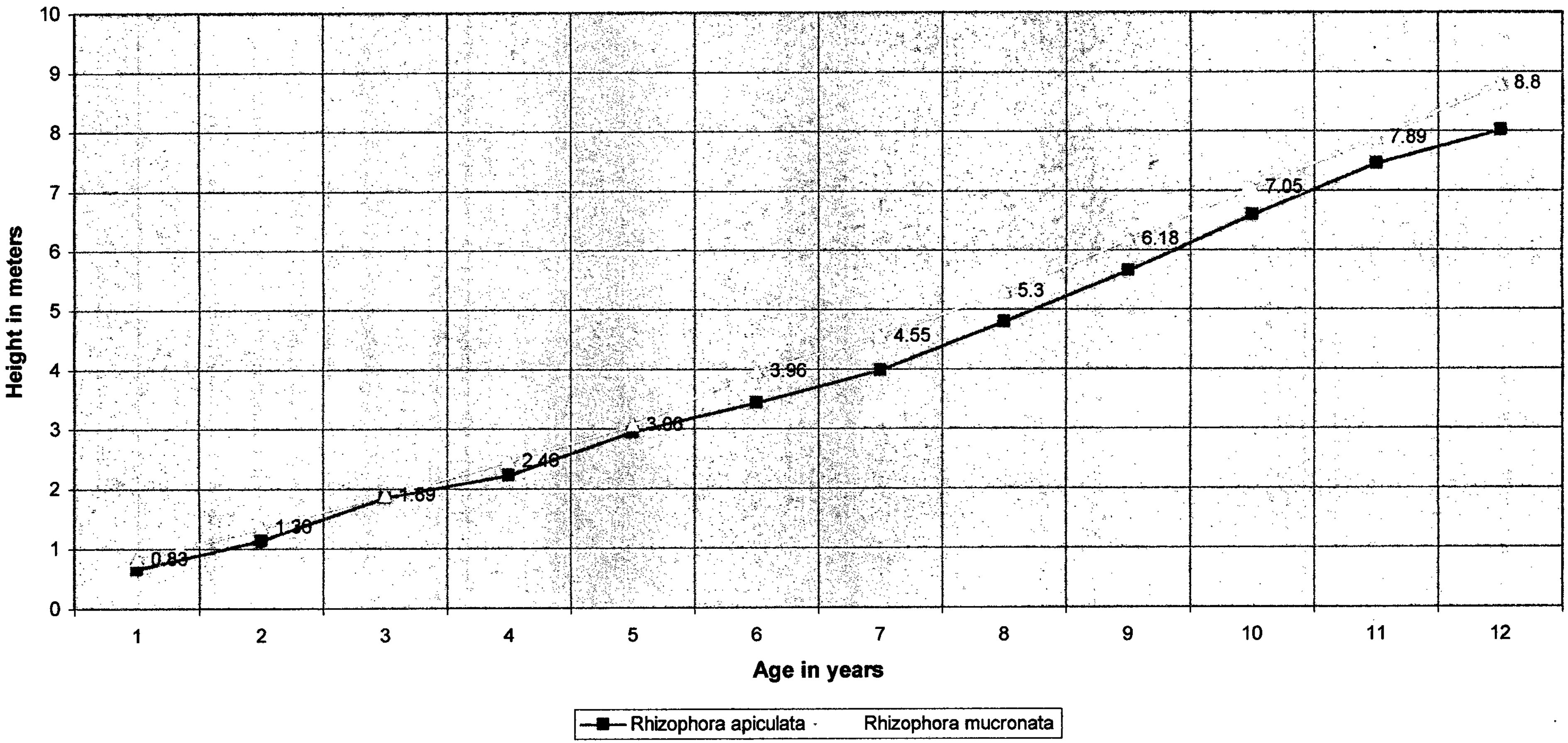
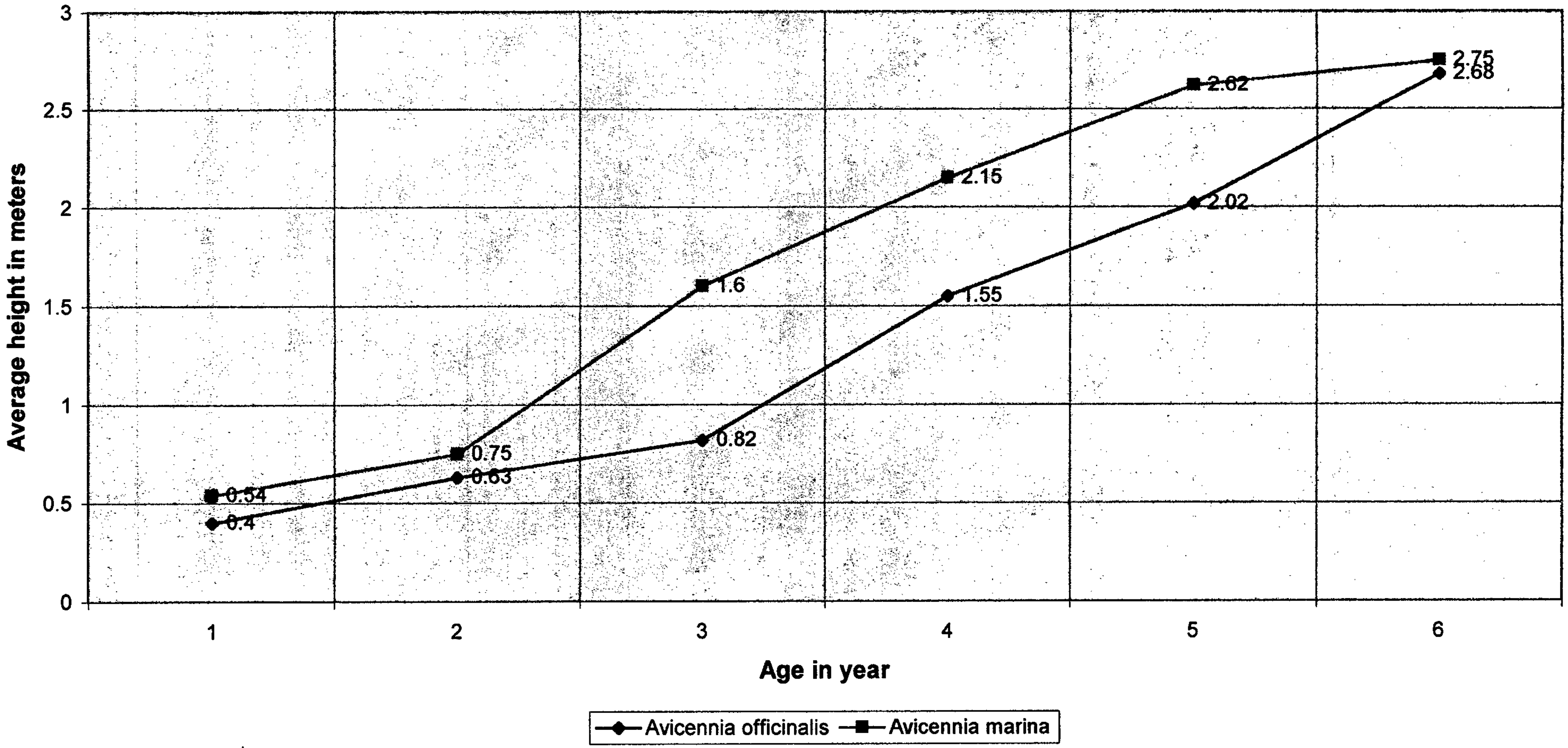


FIGURE-5.3 Growth performance of *Avicennia officinalis* and *Avicennia marina* plantations in Goa



5.2.5 TESTING VIABILITY OF METHOD ON COLLECTION OF WILDINGS OF *Avicennia officinalis* FOR TRANSPLANTING IN THE NURSERY

Material and methods

In some areas close to mangrove nursery at Chorao (Goa) profuse natural regeneration of seedlings of *Avicennia officinalis* was noticed. From these areas total 400 seedlings were carefully uprooted in such a way that 100 seedlings fall in each of the following four height classes viz 5-10 cms, 11-20 cms, 21-30 cms and 31-40 cms. While uprooting and transplanting the seedlings in the nursery extreme care was taken to cause minimum disturbance to the root system. These 400 seedlings were transplanted immediately on the same day in the already filled polythene bags in the nursery. Separate beds were maintained for each of the four groups according to height classes. Survival percentage was recorded at the end of six months from the date of transplanting.

Results

Results obtained have been shown in Table-5.6 given below:

TABLE-5.6

HEIGHT AND SURVIVAL PERCENTAGE OF WILDINGS

S.No.	Height (cms) of seedlings	Survival percentage
1.	5-10	52%
2.	11-20	23%
3.	21-30	11%
4.	31-40	8%

Discussion

Results obtained point out towards the fact that as the height of seedlings increases its transplanting success rate reduces. It seems, root system of *Avicennia officinalis* is sensitive to shock, which it gets on uprooting of the plant. Therefore, extreme care should be taken while uprooting the wildings. This method may be adopted in the plantation area close to the site in which wildings are available, otherwise this method may prove uneconomical due to high cost of transportation. Long distance between the source area and plantation site may badly disturb the root system during transportation and long time taken in the transportation may reduce the chances of plant survival.

Transplanting cannot be done after a certain age, usually about 6 to 9 months and certainly not after the formation of pneumatophores (Qureshi, 1996). Wildings are removed from their natural habitat with a mass of soil around the root system for lesser disturbance to the root system but due to marshy nature of terrain, this becomes difficult many a times.

In Matang, natural regeneration of *Rhizophora* is often bountiful. Wildings of *Rhizophora* which are readily available in the vicinity of seed trees are used as planting stock for plantation establishment (Chan, 1996). In case of mangrove species, profuse natural regeneration takes place in some areas and in a small area hundreds of naturally grown seedlings can be seen. If these seedlings are not thinned artificially most of them die due to congestion. Therefore, wildings from such areas can be easily collected without hampering natural regeneration.

thinned artificially most of them die due to congestion. Therefore, wildings from such areas can be easily collected without hampering natural regeneration.

The planting of naturally regenerated saplings (wildings) is not yet successful in Vietnam. In 1992, the City Forest Research Centre collected 5,000 saplings *Avicennia officinalis*, *A. lanata* and *Sonneratia alba* by using a special iron tube 12-15 cm in diameter and 25-25 cm in length to dig out the saplings and the surrounding soil. The saplings were then planted experimentally to reduce coastal erosion along the Can Thanh coastline. After a month, 90% of the saplings were washed away by the waves and eventually all disappeared (Nam, 1994).

From the experiences of India and Vietnam, we conclude that the younger seedlings give better surviving result but are more prone to washing out therefore, proper site selection should be done and planted seedlings should have either natural or artificial protection against the wave action otherwise washing out of such seedlings may invariably be there.

5.2.6 PLANTING OF SOME MANGROVE SPECIES BY USING FRUIT BROADCASTING METHOD

Material and methods

During day to day fieldwork for many years in Goa, it was observed that in nature *Avicennia* and *Sonneratia* seeds germinate profusely. This natural regeneration was conspicuous in abandoned paddy field and other area falling within intertidal regions along the estuaries. Therefore, experiments were conducted to artificially regenerate areas by fruit broadcasting method by using fruits of *Avicennia officinalis* and *Sonneratia caseolaris*. For the purpose of this experiment two plots of 0.25-hectare area each were laid out at Panchwadi along Zuari estuary. The plots were located in the intertidal region with some growth of grasses but without growth of mangroves. Such plots with growth of grasses were selected so that grasses might obstruct seeds from moving out of the plots during the tides. 5 kg of mature fruits of each species was uniformly broadcasted in two different plots. After a period of six months, seedlings present in the two plots were counted.

Results

581 number of *Avicennia officinalis* and 609 seedlings of *Sonneratia caseolaris* were found in the two different sample plots. The seedlings were more or less uniformly distributed all over the experimental plots.

Discussions

Table-4.3 (Chapter-4) shows that average number of fruits of *Avicennia officinalis* per kg comes to 350. Thus 5 kg of fruits come to 1750 in number. On broadcasting these fruits, we recorded 581 number of *Avicennia officinalis* seedlings in the experimental plot with 33% success. Thus, we conclude that the method is viable in view of its fair degree of success and low cost of regeneration. In case of *Sonneratia caseolaris* seeds are very small in size. As many as 29,953 seeds weight one kg on an average (Table-4.3, Chapter-4). Therefore, as compared to number of seeds broadcasted, the success percentage is very low but once again establishment of 609 number of seedlings in 0.25-hectare area can be graded as viable method especially in view of cost effectiveness of the method.

Qureshi, (1996) reports his findings as follows: *Avicennia marina* can be raised by broadcasting seeds in areas where *Oryza* or *porteresia* grass is growing on the mudflats. The seedlings, as they take root, will be protected by grasses. The broadcasting method is economical and effective. The number of seeds per hectare should be about 6,000 and the average rate of successful germination is about 60%. *Aegiceras corniculatum* seeds can be broadcasted into grass covered mudflats. In all cases the percentage of survival does not exceed 40 to 50%.

5.2.7 STUDY OF ZONATION PATTERN IN MANGROVES OF GOA

Material and methods

While working in the field conspicuous zonation in mangroves of Goa was seen. Therefore, the species occurring in the estuary mouth region and upstream regions were recorded both in Estuarine region and Landward region. General pattern of soil types, tidal inundation characteristics, and naturally occurring species were recorded.

Results

Results obtained on zonation studies have been shown in the Table-5.7. It can be seen from the Table that species composition in mangroves varies from zone to zone.

Discussion

Zonation studies have special significance in artificial plantation of mangroves. Presence of a particular mangrove species in a particular region or zone indicates its suitability for planting in that area. Therefore, zonation studies should be carefully done in the area selected for artificial regeneration and natural zonation pattern should be followed in general. Macnae (1996) attributed the distribution of mangrove trees and hence their zonations to the interaction of (a) frequency of tidal flooding (b) salinity of soil water and (c) water logging of the soil (drainage). Walter and Steiner (1936) consider the degree of flooding, soil nature and salinity as important factors. With respect to tides, Chapman (1976) considers that the most important factor is the number of consecutive days with no tidal flushing.

Whereas the degree of flooding, which depends on soil level, is important in the establishment and dispersal of propagules, its effect on mature stands may be less pronounced. Rabinowitz (1978) has suggested that the morphology of the propagules controls the zonation of mangroves in Panama because smaller propagules can be transported further inland through already established vegetation by tides. Johnstone and Frodin (1982) who have attempted more thorough analysis have proposed six types of like causes of zonation in mangroves viz. Inundation and depth of water; Wave action; Drainage; Salinity/freshwater regime; Substrate; Biota and biotic interactions.

TABLE-5.7

NATURAL ZONATION IN ESTUARINE MANGROVES OF GOA

Parameters	Estuary mouth region		Upstream region	
	Estuary-side region	**Landward region**	**Estuary-side region**	**Landward region**
Soil type	Clayey sand to sandy clay	Silty clay	Clayey sand to sandy clay	Silty clay
Tidal inundation characteristics	Inundated daily even during neap tides	Inundated only during high tides	Tides have little influence in the up stream region. Fresh water run off has its influence in the region	
Naturally occurring Mangrove species	*Rhizophora mucronata* *Rhizophora apiculata* *Avicennia officinalis* *Avicennia marina* *Sonneratia alba* *Ceriops tagal*	*Bruguiera gymnorrhiza* *Bruguiera parviflora* *Acanthus ilicifolius* *Derris heterophylla* *Excoecaria agallocha*	*Avicennia officinalis* *Avicennia marina* *Kandelia candel* *Sonneratia caseolaris* *Acanthus ilicifolius*	*Excoecaria agallocha* *Aegiceras corniculatum* *Acrostichum aureum* *Derris heterophylla*
Recommended Species for planting	*Rhizophora mucronata* *Rhizophora apiculata* *Avicennia officinalis* *Avicennia marina* *Sonneratia alba* *Ceriops tagal*	*Bruguiera gymnorrhiza* *Bruguiera parviflora* *Excoecaria agallocha*	*Kandelia candel* *Sonneratia caseolaris* *Avicennia officinalis* *Avicennia marina*	*Excoecaria agallocha* *Aegiceras corniculatum*

5.2.8 DETERMINATION OF APPROPRIATE DEPTH OF SOWING, LENGTH AND WEIGHT - A CASE STUDY OF *Ceriops tagal*

Material and methods

(i) Appropriate depth of sowing

A total of 240 healthy and mature propagules of *Ceriops tagal* were collected from mother trees. Four different beds were laid down and sixty propagules were planted at a spacing of 30X30cms in each bed. Collection and planting of propagules was done on the same day. The beds were designated as IA, IB, IC and ID. In bed No. IA half portion of propagule was inserted in the soil. Similarly in bed No. IB, IC and ID propagules were inserted at 1/3rd, 1/4th and 1/5th portions in the soil respectively. Regular observations were taken in the experimental beds regarding total number of propagules sprouted and number of seedlings survived at the end of six months from the date of planting. In order to compare the results of this experiment with what is happening in the nature, following experiment was conducted:

Ten profusely fruiting healthy mother trees of *Ceriops tagal* with lot of germinating seedlings around these mother trees were selected in Middle Andaman Island. Twenty freshly germinated propagules from each locality were uprooted carefully without damaging the roots. Likewise a total of 200 propagules were collected. A ring was marked on the portion of the propagules, which separates the portion above and below the ground level. Total length of all such 200 numbers of freshly germinated propagules and length of the portion of propagule below the ground level was measured. Then the ratio of length of propagule below the ground to their total length was recorded using the formula

A/B = C

Where,

A- Length of portion of propagule below the ground level

B- Total length of propagule

C- Ratio of 'A' and 'B'

(ii) Length and weight of the propagules

500 healthy propagules of *Ceriops tagal* were collected and their lengths were measured to find out the minimum, maximum and average lengths of the propagules found in Middle Andaman. The propagules were thoroughly mixed and the average number of propagules in one kilogram was found out. Ten readings were taken to determine the average number of propagules per kilogram.

Results

The sprouting percentage and the survival percentage of *Ceriops tagal* planted at different depths in different beds are shown in the Table-5.8. Sprouting percentage is very low in bed IA and maximum of 92% in bed ID. Similarly the survival percentage is 23% in bed IA, which is very low compared to 80% in bed ID.

From the experiments it was found that the maximum ratio between the portion of the propagule below the ground to the total length is 0.32. The minimum and the average ratio was found to be 0.15 and 0.22 respectively. The minimum length of propagules found in this region is 18 cms, the maximum length was found to be 29 cms and the average length of propagule was worked out to be 22 cms. The average number of propagules per kg comes to 120. The results have been discussed in the subsequent part of this chapter.

TABLE-5.8

GERMINATION AND SURVIVAL PERCENTAGE OF *Ceriops tagal* AT DIFFERENT DEPTH OF SOWING

Bed No.	Number of propagules planted	Total Number of propagules sprouted	Sprouting %	Survival %
IA	60	18	30	23
IB	60	31	52	47
IC	60	44	73	62
ID	60	55	92	80

Discussion

Ceriops tagal is a medium size tree with conspicuous pneumatophores and buttresses. This species is extremely rare in Goa but abundantly found in many areas of Middle Andaman. Plate-5.9 shows an isolated tree of *Ceriops tagal* at Yerrata (Middle Andaman). Plate-5.10 gives a close-up view of buttresses in *Ceriops tagal*.

The sprouting percentage results show that in beds where 1/2, 1/3, 1/4 and 1/5 portion of the propagules were inserted only 30%, 52%, 73% and 92% sprouting was found respectively. Survival percentage was studied in these beds after six months form the date of planting and it was found that 23%, 47%, 62% and 80% in beds IA, IB, IC and ID respectively.

It is seen that mortality in propagules was increased with increase in depth of planting. In case of deep insertion of propagules in soil, they are unable to breathe properly and the lack of oxygen might have caused the death of propagules. To get maximum survival, insertion of one-fifth portion of propagules in the soil was found to be most favourable. But with shallow insertion of propagules in the soil care should be taken to provide them protection against wave and wind action, otherwise propagules may uproot and result in low success rate. The same phenomenon was also studied in nature.

In case of naturally sprouting and establishing propagules of *Ceriops tagal* on the ground around the mother tree, the average ratio of length of propagules below the soil to its total length was found 0.22. This further confirms that for the best survival percentage only one-fifth portion of the propagule should be inserted in soil. Plate-5.11 shows propagules in *Ceriops tagal.*

Hong (1996) has reported similar types of observations from Vietnam. He says that one quarter to one third of the propagules should be buried. If the propagule is buried too deep, mud will block the tentacles and the hypocotyl cannot respire which makes rooting difficult and leads to death of the propagule. However, if the hypocotyl is inserted too shallowly, it will be easily washed away by the waves and tides.

Ceriops tagal is a sensitive species and raised in those areas, which get inputs of fresh water from river or drainage canals for at least 2 to 3 months. In saline conditions the species has a prolonged germination period and their rate of survival is very poor. Normal germination period for *Ceriops tagal* in Pakistan has been reported as 30-40 days (Qureshi, 1996).

PLATE- 5.9

An isolated tree of

***Ceriops tagal* at Yerrata,**

Middle Andaman

PLATE- 5.10

A close up view of

buttresses in *Ceriops tagal*

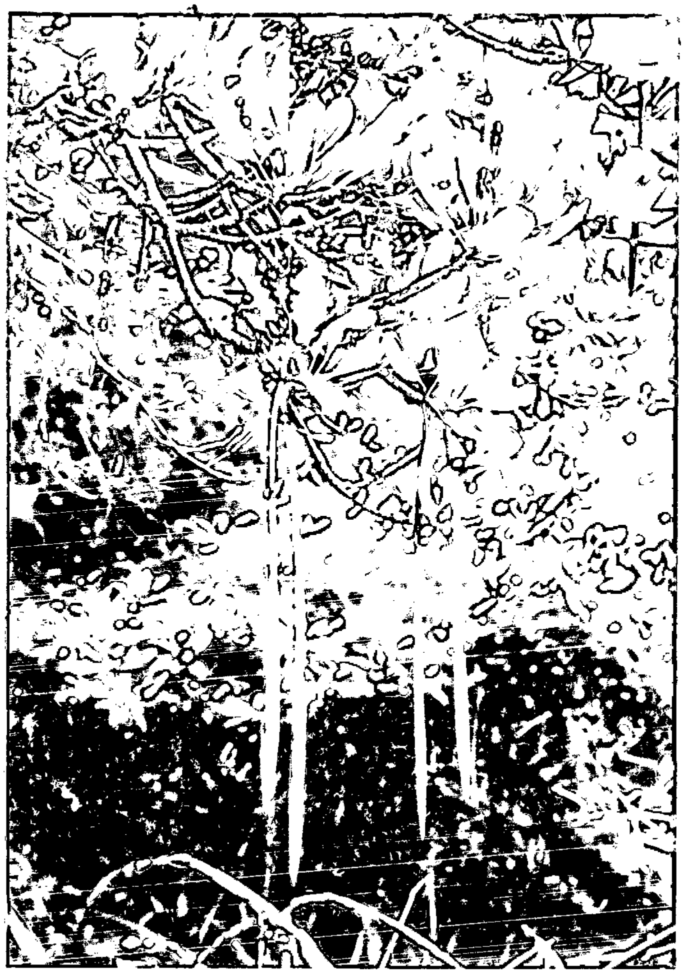


PLATE- 5.11

Propagules in *Ceriops tagal*

CHAPTER-6

CONSERVATION AND MANAGEMENT OF MANGROVE ECOSYSTEM

CHAPTER-6

CONSERVATION AND MANAGEMENT OF MANGROVE ECOSYSTEM

6.1 NEED FOR THE CONSERVATION AND MANAGEMENT

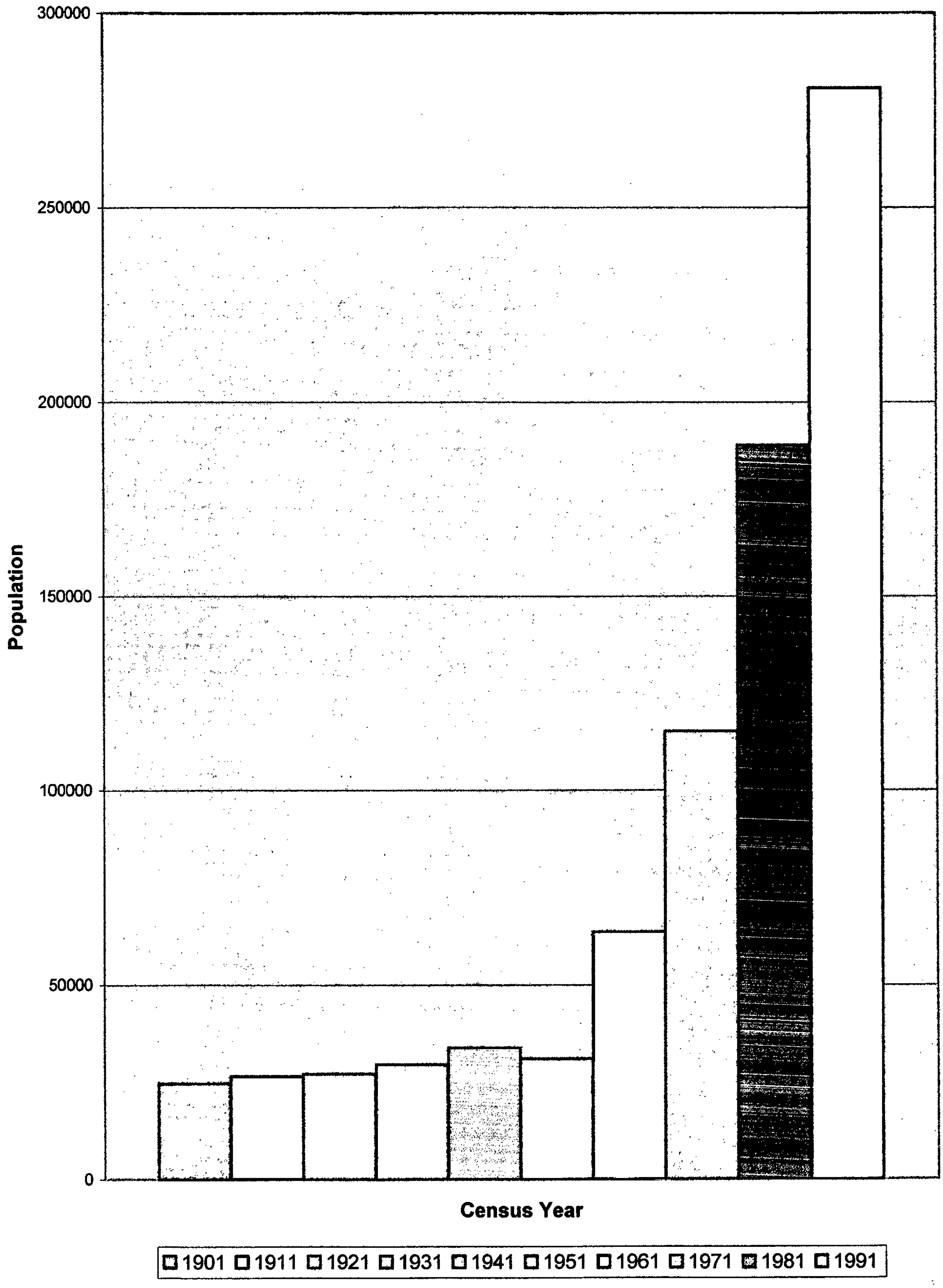
The need for conservation and management of mangrove ecosystem is strongly felt today primarily due to increasing human population year by year and consequent increase in pressure on mangrove ecosystem. As the population grew in the coastal areas, the pressure on the mangrove forests increased for timber, fuelwood, fodder and other non-timber forest produce (N.T.F.P). Increasing population and economic development invariably increase the demand for forest products and the forest land (Soemodihardjo *et al.*, 1996). Ever-increasing population pressure had caused dramatic changes in the mangrove ecosystem throughout the world (Saenger *et al.*, 1983). After 1961, population of Andaman and Nicobar Islands has risen very sharply (Figure- 6.1).

From the available literature (Blasco, 1975; Untawale, 1985), it is clear that the condition of Indian mangroves is highly degraded as a result of lack of awareness, planning and pressure of resource use. Growing awareness of the protective, productive and social functions of tropical mangrove ecosystem has highlighted the need to conserve and manage them sustainably (FAO, 1994). Appropriate management of mangrove ecosystem can ensure its conservation for environmental benefits and at the same time it can ensure optimum supply of various forest and other produce to local people to meet their day to day basic requirements. With the proper planning on scientific lines, the supply of various produce from the ecosystem can not only be maintained on sustainable basis but also can be further improved. It is necessary to undertake management plans to conserve the mangroves (RSAM, 1992). Various aspects of Indian mangrove have been studied so far but no concrete attempts have been made to protect and conserve these resources. Conservation and management of mangrove genetic resource is an imperative need to prevent further deterioration (Jagtap *et al.*, 1993).

Role of management is not confined only to these environmental and economic benefits. It can open many new avenues for self-employment like eco-tourism, fishing, honeybee keeping, mangrove forest produce based cottage industries etc. for the local unemployed people (FAO, 1994), which can play a very crucial role in socio- economic upliftment of the local communities.

Management is also required to effectively tackle various problems, which have originated due un-wise interference of human beings in mangrove ecosystem. Several International funding agencies viz. UNESCO, UNDP, WWF, IUCN etc have shown much interest to conserve and protect the mangrove ecosystem (Naskar *et al.*, 1999).

Figure-6.1 Population of Andaman and Nicobar Islands



6.2 MANGROVE CONSERVATION AND MANAGEMENT ISSUES

Mangrove conservation and management issues can be divided into two broad categories, namely regulatory issues and developmental issues. During the course of present study, following issues were noticed in Goa and Middle Andaman:

6.2.1 Regulatory issues

Regulatory issues pertain to variety of problems, which have cropped up in mangrove forests. These issues call for adoption of appropriate management practices immediately to conserve the unique ecosystem (Anonymous, 1989).

(a) Indiscriminate tree felling and lopping

Indiscriminate tree felling and lopping of mangroves mainly for the firewood, fodder and timber result in the degradation of mangroves. It was observed in Goa that local people lopped mainly *Avicennia officinalis* and *A. marina* which grew quite big in size among the mangrove trees. Tree felling and lopping were mostly seen in the areas close to human habitation. In Middle Andaman, lopping of *Bruguiera parviflora* for fodder and felling of *B. gymnorrhiza* for getting poles were noticed. Table-6.1 gives information on mangrove related offence cases booked in Middle Andaman in different years.

TABLE-6.1

MANGROVE RELATED OFFENCE CASES IN MIDDLE ANDAMAN

Year	Number of Mangrove related offence cases booked	Total quantity of forest produce seized			
		Fuel wood	Poles	Ballies	Seeds
1995-96	4 Cases	Nil	17 Nos.	100Nos.	Nil
1996-97	7 Cases	-	19 Nos.	163 Nos.	Nil
1997-98	6 Cases	35 Bundle	20 Nos.	454 Nos.	-
1998-99	14 Cases	-	-	773 Nos.	1. 160 kgs. 2. 10200 Nos.
1999-2000 (up to June, 1999)	1 Case	-	-	16 Nos.	-

SOURCE: Divisional Forest Officer, Middle Andaman

Plates- 6.1, 6.2 and 6.3 show remnants of indiscriminate felling of mangrove trees in Middle Andaman, illegal collection of mangrove firewood at Chorao (Goa) and lopping of *Bruguiera parviflora* for fodder in Middle Andaman respectively.

Indiscriminate and over-exploitation of mangroves resulted in resource depletion and posed serious threats to the ecology and environment of mangrove bearing coastal areas (Untawale, 1984, 1987).

Untawale (1996) reported over-exploitation and deforestation of mangroves for fuelwood and fodder in Goa. Qureshi (1996) reported lopping of mangroves in Pakistan for fuelwood and fodder. Naskar & Mandal (1999) reported that wood cutting and poaching of firewood had increased day by day in Sundarbans to meet the needs of local rural and urban people.

Illegal mangrove tree fellings have also been reported from abroad. In Vietnam, demand for mangrove timber, poles and firewood is far larger than the supply. People come to forests and use subtle tricks such as sawing the trees at ebb tide, with other relative guarding outside to warn of danger and transporting the timber away in midnight. Sometimes, the trees are tied to the sides of the boat and thrown into the river, if discovered (Cuong, 1994).

PLATE- 6.1

Remnants of indiscriminate felling of mangrove trees in Middle Andaman

PLATE- 6.2

Illegal collection of mangrove firewood at Chorao (Goa)

PLATE- 6.3

Lopping of *Bruguiera parviflora* for fodder in Middle Andaman

(b) Indiscriminate conversion

Indiscriminate conversions of mangroves bearing areas for aquaculture, agriculture, human habitation and industrial purposes have wiped out mangroves from the many areas. There are examples in Goa where mangroves bearing areas were converted for the above mentioned purposes. Some mangrove area has already been converted for prawn culture at Chorao (Goa). Recently, Fisheries Department of Goa government has sought permission of the Forest Department to further clear the mangroves for development of aquaculture at Chorao. Along the Mapusa estuary (Goa), mining related activities have adversely affected the mangroves. At Goa, several bunds were noticed in different parts of the state which were constructed to reclaim the mangrove areas. Conversion of mangrove areas for agriculture, brackish water fisheries, prawn and shrimp farm, salt pans, development of ports and harbours, tourist spots, cities had several adverse affects on the natural regeneration process (Clough, 1982).

In Middle Andaman, the Revenue Department has allotted mangrove-bearing land for human settlement and agriculture/ horticulture. These mangroves deforested and cleared naked lands become subject to soil erosion during tidal inundation or rain (Naskar & Mandal, 1999).

Interference with the free flow of tidal water and of fresh water from the landward side may alter the character or destroy the normal vegetation of the mangrove swamp. In Port Blair, reclamation by means of embankments has rendered large areas unfit for the growth of mangroves and marshy blanks have resulted (Sahni, 1957).

The total wetland area which has been converted for other uses is about 40 million ha in India, as compared with 10 million ha in Indonesia and about 2 million ha in Malaysia (Untawale, 1992). During the last two centuries more than 50% mangrove areas in the Indian part of the Sundarbans have been reclaimed and converted to agricultural fields, brackish-water fisheries and rural habitations (Naskar, 1985). Mangrove areas of the undivided Sundarbans have been reduced by more than 50% during the last two centuries (Chanda, 1977).

Several reports on indiscriminate conversion of mangrove areas have come from various part of the world. Mencer and Hamilton (1984) reported that during the last two centuries, vast areas of the mangrove forests of the world had been reclaimed to shrimp farms and brackish water fisheries in the South-East Asian countries. Shrimp and crab rearing is tremendously profitable when compared with forestry business (Hong, 1996) and the fact lures the people to convert mangrove areas.

In Peninsular Malaya (Malaysia), about 10,500 ha mangrove lands have been converted during 1955 to 1980 for agricultural purposes (Razani, 1982). Several hectares of these mangrove cleared lands also remain fallow or idle due to acid sulphate in these soil (Ong, 1982). Similarly, in Sarawak, about 4,000 ha mangrove lands have been reclaimed for agriculture from 1933 to 1982 (Chai, 1982). In Peninsular Malaya alone, 500 ha mangrove areas have been cleared for aquaculture. Besides these agricultural and aquacultural utilisation of mangrove areas in Malaysia, the rapid growing urbanisation, mining, over- exploitation, cross bund construction on rivers, have caused large-scale deforestation or mortality of mangroves like other world mangals (Chan, 1988).

(c) Industrial pollutants

When industrial pollutants are discharged into the rivers without giving proper treatment, they adversely affect the mangroves and hinder its natural regeneration (Clough, 1982). This problem is not severe in Goa and Middle Andaman but in some regions of the world, it is one of the major problems.

Within and in the vicinity of Karachi, there is pollution resulting from the steady growth of a major industrial city of over a million people. Apart from untreated domestic sewage, which flows into the rivers, streams and creeks, there are significant industrial discharges from major industries such as steel mills, refineries, power stations, tanneries and textile mills. Tanneries perhaps represents the main source of pollution, since the waste has a high metal content which is less easy to control (IUCN, 1987a).

(d) Encroachments

The entire mangrove areas have not been surveyed from the point of view of ownership. It is believed that people might have encroached upon the Government's mangrove forest lands. At some places in Goa, local people were seen cultivating paddy on government land along the banks of the estuaries after uprooting the natural and planted seedlings.

In Vietnam, some households, living far from the forestry station, steadily encroach and destroy mangroves for building aquaculture ponds (Hong, 1996).

(e) Ownership of Land

A considerable mangrove area in Goa belongs to *Communidade* (Village community) and private people. As ownership of this land is not with the government, it is relatively difficult to conserve and develop the mangroves over such lands if the owners of these lands do not extend co-operation.

Qureshi (1957) emphasised the need to transfer all mangrove forests under control of Forest Department for scientific management.

(f) Traditional method of fishing

In the traditional method of fishing in Goa and Middle Andaman, dragnets are used along the rivers where young mangrove seedlings may be there. At the time of dragging the net, young seedlings get entangled in the nets and are uprooted. Thus, this method of fishing hampers regeneration of mangroves.

Large-scale shrimp/prawn seed collection cause tremendous detrimental effect on the aquatic environment of the mangroves of Sunderbans (Naskar & Mandal, 1999).

Fishermen, women and their children usually gather edible molluscs and catch fishes in the plantation area. These activities are also a threat to the seedlings (Hong, 1996).

(g) Movement of barges

Barges are used in Goa for carrying iron ore. While sailing through the estuaries, barge movement gives rise to strong waves, which sometimes damage the young mangrove seedlings.

Rhizophora seedlings are broken by the boats passing through the plantation (Hong, 1996).

(h) Wildlife

Rarely, wildlife was also seen destroying and damaging mangroves in Middle Andaman to little extent. Deer were seen damaging the young plants of *Avicennia* by eating its foliage. Population of spotted deer and barking deer is substantial in Middle Andaman as evident by day to day field observations. There are no carnivorous like tiger, leopard etc who feed on deer but deer poaching is common in Andaman and Nicobar Islands.

In Vietnam, after the Vietnam War, the number of wild boar increased rapidly. Their habitat and food source was large clumps of *Phoenix paludosa* and *Acrostichum aureum.* In 1989, when the burnt *Phoenix* was replaced by planted *Rhizophora mucronata*, wild boars destroyed the newly planted species by digging up the propagules. After 4 months, 58% of experimental planting of *Rhizophora mucronata* on high land was destroyed (Nam, 1994).

In Middle Andaman, there is no threat to mangroves from the wild boars. Wild boars are hunted by **Jarwa tribe**, which is their favourite food but deer are not eaten by them as they worship deer as pious animal.

In Vietnam, troops of long tailed macaques (*Macaca fascicularis*) gathered in newly planted areas to search for crabs and molluscs, trampled and damaged the *Rhizophora mucronata* seedlings (Hong, 1996). Monkeys are not found in Middle Andaman. Wildlife is not a serious threat to mangroves in Goa and Middle Andaman.

(h) <u>Cattle pressure</u>

In many areas, cattle mainly goats, buffaloes and cows were seen browsing the leaves of some mangrove species. They also trampled the young mangrove seedlings. This problem was more severe in the areas close to human habitation where owners of the domestic cattle let them free for grazing. Grazing / browsing in mangrove of Central West Coast of India have been reported by Untawale (1996). Pressure from overgrazing has resulted in stunted trees in some mangrove area of Pakistan (Qureshi, 1996).

Domestic animals in Vietnam are considered as hazards to replanted mangroves located near river mouths. They trample the planted seedlings and eat the foliage (Hong, 1996).

(i) Natural stress

Mangroves are also subject to stress from cyclones, typhoon and strong wave action (Naskar & Mandal, 1999). Mangroves of Andaman and Nicobar Islands are prone to damage by these natural agencies because of its geographical location.

(j) Wood -borers

In some mangrove areas like Chorao in Goa, wood-borers attack on plants was noticed which ultimately resulted in the death of the plants. Several insects (caterpillars) and molluscs wood-borers eat away the mangrove foliage and damage the wood as well (Naskar & Mandal, 1999).

(k) Infestation by Barnacles, Oysters, Crabs and Gastropods

Barnacles are small cones shaped shellfish that attaches itself to object under water. Barnacles, in Goa, were seen attacking newly planted propagules. Barnacles attachment to young seedlings interferes with respiration and photosynthesis so delaying seedlings growth (Hong, 1996).

Damages to the young leaves and plumules of *Rhizophora* and *Ceriops* by the Oysters were noticed in Middle Andaman. Due to oyster attack, large areas of *Kandelia candel* planted in the central and north coast of Vietnam have become bushes with lot of branches (Hong, 1994).

Crabs attack on mangroves was not noticed in Goa but in Middle Andaman, it is a serious problem. Crabs generally attack young seedlings and girdle the root collars. Crabs also eat the fleshy tissues of the propagules. During the course of experiments in mangrove nursery in Middle Andaman, crabs were seen eating seeds of *Sonneratia* and young leaves of *Avicennia* seedlings.

Sesarma crab attacks propagules and saplings of *Rhizophora* and *Ceriops*. The damage is inflicted on young seedlings by nibbling into the young propagules until they are completely girdled or even bitten through. Attacks occur just above or below the mud surface (Chan, 1994).

Gastropods are also a big problem in Middle Andaman. They were seen eating young leaves and flowers of mangroves. Eating of leaf surface and young propagules by gastropods have been reported by Untawale (1996).

(l) <u>Marine Algae</u>

Presence of marine algae hampers establishment and growth of young mangrove seedlings, however, it is not a serious problem in Goa and Middle Andaman.

In dry season, marine algae such as *sargassum, syzigium* and some other *Rhodophyta* species are washed ashore. Mangrove plantations at Can Gio in particular and along the coast line of Vietnam in general have suffered a high mortality or retarded growth due to these algae. They choke the seedlings to death or cling to the hypocotyl, giving additional weight, which results in bending or breakage of the stem of the seedlings (Cabahug *et al.*, 1986)

(m) Pests

The larvae of *Parasa* species (Limacodidae- Lepidoptera) is a common pests on *Rhizophora.* It is a leaf-eating caterpillar, which damage the foliage very badly. Plate-6.4 shows pest attack on foliage of *Rhizophora* planted along Mandovi estuary at Ribander near Panaji (Goa).

In Middle Andaman, large numbers of buds were noticed in the genus *Sonneratia* but hardly 1% of them bloomed into flowers (personal observation). This was probably due to some pest attack. Propagules of *Rhizophora* are often attacked by *Poecilips fallax* (Scolytidae- coleoptera) which are rarely inundated by tide (Agaloos, 1994).

The pest appears at the beginning of the dry season (Nov-Feb) in mangrove areas. Therefore, if propagules are collected during this time, the death rate of the seedlings will be high. In the 1980's when *Rhizophora apiculata* was transported in great amounts from Minh Hai Province to Can Gio, which take many days by boat, these beetle (*Poecilips fallax*) destroyed a large number of propagules (Hong, 1994). From December to April, in a pure population of *Avicennia*, *P. fallax* caused epedemic defoliation and new leaves formed in the next rainy season (Hong, 1996).

At some places in Can Gio, *Rhizophora apiculata*, *R. mucronata* and *Ceriops tagal* were planted and the growth of the seedlings was inhibited by competition from *Acrostichum aureum* and *Phoenix paludosa* for living space and light (Nam, 1994).

Deforested mangrove areas are usually occupied by *Acrostichum aureum*, which is difficult to eradicate subsequently. Sometimes the dense growth of *Acrostichum aureum* and *Acanthus* species act like pest and do not allow the regrowth of the economic mangrove tree species, in the mangrove felled areas (Teas, 1979).

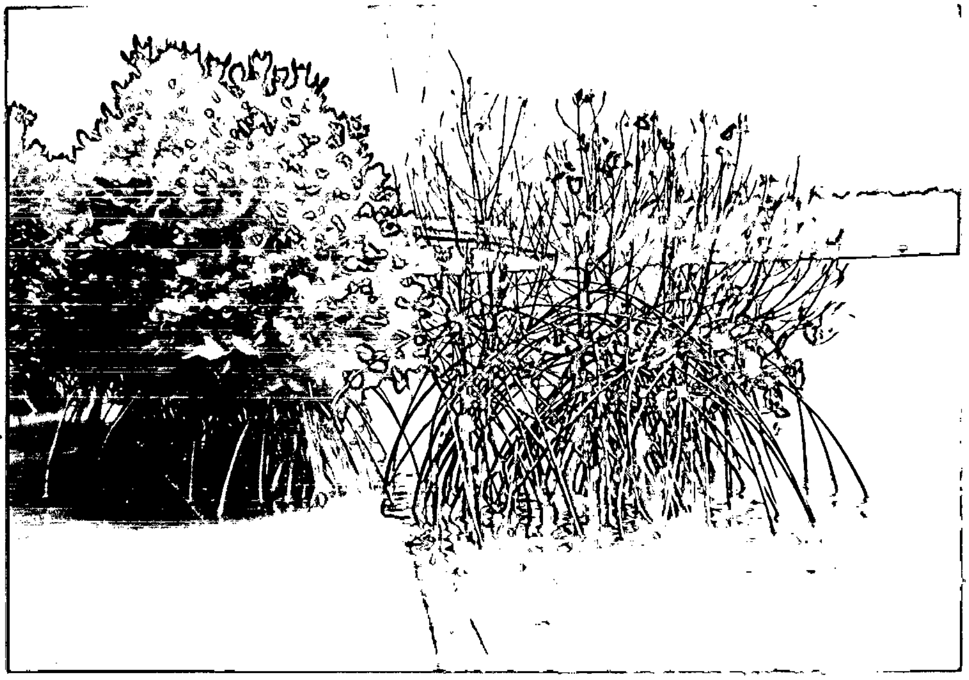


PLATE- 6.4

Pest attack on foliage of *Rhizophora* planted along Mandovi estuary at Ribander near Panaji (Goa)

(n) Grass cutting

Over a considerable area along the banks of the estuaries, thick and tall grass occurs naturally both in Goa and Middle Andaman. Local people use this grass for thatching purposes. This grass protects young mangrove seedlings from the strong wave action and help in the establishment of the young seedlings. But, unfortunately at the time of cutting and removing the grass, young mangrove seedlings are also damaged.

(o) Mortality of mangrove trees

Although unusual mortality of mangroves was not noticed in Goa but mortality of big patches of mangroves were noticed at Baludera near Baratang (Middle Andaman Island). At Shoal Bay No. 18 (South Andaman Forest Division), *Bruguiera* trees in approximately 1 ha area have become dry. At Tarmugli Island, *Avicennia* trees in about 50 ha area have dried.

Obstruction and diversion of water flow at Shyamkund, (Middle Andaman) for culvert construction, resulted in death of mangroves in about 0.5 ha area (personal observation). Diversion of estuary/ creek flow is very common in Sundarbans, which makes the waterways in unwanted situation for the tidal flow (Naskar & Mandal, 1999).

The climax species in the Sundarbans of Bangladesh, is *Heritiera fomes*, which constitute almost 73% of the growing stock (Das & Siddiqi, 1985). Large-scale mortality of *Heritiera fomes* has been reported in mangroves of Bangladesh, which may be due to inadequate supply of upstream freshwater and for the age of the plants (Naskar & Mandal, 1999).

Root causes of the problems involving regulatory issues

It is always advisable to examine root causes of the problems so as to adapt appropriate strategies to eliminate or minimise those factors itself, which give birth to the problems. This will minimise the incidences of re-occurrence of the problems. It has been rightly said that prevention is better than cure. Following are the root causes of the various problems as learnt during the field study in Goa and Middle Andaman.

1. **Poor financial condition** of the local inhabitants force them to depend on mangroves for their fuelwood, timber and fodder requirement. Whether it is legal or illegal, they collect their requirement from mangrove forests without paying any cost.

2. **Increasing population** results in more biotic pressure on mangroves.

3. **Lack of education and awareness** among masses regarding importance of mangroves.

4. **Improper planning of developmental activities** likes aquaculture, agriculture, human habitation, mining and industrialization etc.

5. **Short supply** of fuelwood, timber and fodder at low or reasonable price.

6. **Release of untreated pollutants** in the form of industrial waste into the rivers.

7. **Greed** of some people to earn easy money may inspire them for felling of mangroves.

8. **Ignorance** about the rules and regulation regarding conservation of mangroves.

9. So far, no **systematic survey of mangroves** has been done in the state to ascertain their area and ownership and land on which they grow. Taking advantage of the situation, some people might have encroached the areas under mangroves. The first step in the management of mangroves forests should be survey and demarcation to bring them under scientific management (Qureshi, 1957).

10. Mangroves also occur on the private and *communidade* (Village community) land. The **ownership of this land** is not with the Government. This may, sometimes, give rise to conflict with the land-owner over the mangrove conservation issue.

11. Geographically mangroves are widely distributed. Due to their **scattered occurrence**, protection of mangroves becomes difficult.

12. There is acute shortage of staff and other infrastructural facilities with the government for protection of mangroves.

Action points to overcome problems involving regulatory issues

Mangrove conservation and development efforts taken by the Government of India, Government of Goa and Andaman-Nicobar Administration so far have been successful upto a significant extent. The efforts have definitely reduced the degree of problems but problems are still there. There is scope for further improvement in the situation by eliminating or minimizing the problems. Following action points may be helpful in the conservation and management of mangroves:

1. Patrolling

At present, Forest Departments in states/union territories do not have sufficient staff and infra-structural facilities like motor boats, communication network etc to take up patrolling work effectively. Procurement of speedboats, wireless sets and posting of additional staff may improve the situation. Strengthening of intelligence network may further facilitate management by providing information about the offenders. Severe punishment to the offenders under the law may act as deterrent for the others. Regular patrolling in the creeks is necessary to check possible destruction of mangrove habitat (Anonymous, 1997).

In Vietnam, the facilities, means of transportation and communication system of the guard of the forest network are poor (Hong, 1996).

During the course of study in Middle Andaman, illegal collection of fruits of *Xylocarpus granatum, X. moluecensis*, *Nypa fruticans*, and *Heritiera littoralis* was noticed. Local agents engage the people for illegal collection of mangrove fruits. These fruits are ultimately exported to mainland through the main agents at Port Blair. Probably, these mangrove fruits are used for making some medicine. Indiscriminate collection of mangrove fruits on large scale hampers their natural regeneration. Vigil in the field, jetties and harbours during the fruiting period may control the illegal collection of mangrove fruits. Information gathered on fruiting periods can help us in planning out strategy for safeguarding mangroves (personal observations and experience).

2. Legislative needs

Drag net fishing has done great harm to young mangrove seedlings. Ban on fishing by using dragnets, in the areas having seedlings of less than five years of age, is the need of the hour. Govt. of Goa has already banned felling of 15 species of mangroves for a period of 10 years under **Goa, Daman and Diu Preservation of Tree Act, 1984** (Notification No. 8/ 10/ 83- FOR Dated 11.09.90.). This protection is desirable for all the mangrove species but the need for total ban on mangrove felling/ lopping may be periodically reviewed. For Andaman and Nicobar Islands, a suitable enactment is necessary to stop felling of mangroves in Revenue and Private areas (Anonymous, 1997). Speed limit for the barges may be prescribed in the areas having young mangrove seedlings so that these seedlings are least damaged by wave action. Strict implementation of anti-pollution laws may put a control on the industrial and other wastes being discharged into the creeks, estuaries and rivers. There should be ban on the removal of the grasses along the banks of the estuaries so that young mangrove seedlings are not damaged while cutting grasses. Mangrove forests may also be notified as Reserve or Protected forests as per requirement of the specific area in order to provide effective protection to them. Suitable mangrove forests areas can also be brought under the cover of Sanctuary or National Park for bio-diversity conservation.

Indian Forest Act, 1927 and **Wildlife (Protection) Act, 1972** provide protection to flora and fauna (without mentioning anything specific to mangroves). These acts can also be used to conserve flora and fauna of mangrove ecosystem, prevent mangrove ecosystem related offences and to deal with the offenders who violates provision of these acts. Since 1927, Indian Forest Act was applied to mangrove forest of Sundarbans and these were declared as 'reserved' (Naskar & Mandal, 1999).

Forest (Conservation) Act, 1980 was enforced by the Government of India which says that no forest area shall be diverted for any non-forestry purpose without prior approval of the Government of India. This act has proved very effective in preventing diversion of mangrove forest areas for non-forestry purposes.

Environment (Protection) Act, 1986 is a very- important act, which has played a crucial role in conservation and management of mangrove ecosystem. Under Rule 5 (3) (d) of the Environment (protection) Act, 1986; the Government of India has declared the Coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (in the landward side) upto 500 from meters from the High Tide Line (HTL) and the land between the Low Tide Line (LTL) and HTL as **Coastal Regulation Zone**. The Government of India has put several restrictions on industrial and other activities in this zone in order to protect the environment in coastal areas. For the purpose of this notification High Tide Line means the line on the land upto which the highest water line reaches during the spring tide.

The distance from the High Tide Line (HTL) applies to both sides in the case of rivers, creeks and backwaters and may be modified on a case to case basis while preparing Coastal Zone Management Plans. However, this distance shall not be less than 50 meters or the width of the creek, river or backwaters whichever is less. Under the Coastal Regulation Zone, prohibited activities include-

(a) Discharge untreated water and effluents from industries, cities or towns and other human settlements.

(b) Dumping of city or town water for the purpose of land filling or otherwise.

(c) Land reclamation, bunding or disturbing the natural course of sea water with similar obstructions except those required for control of coastal erosion and maintenance or clearing of water ways, channels, ports and for the prevention of the sandbars and also except for tidal regulators, storm water drains and structures for prevention of salinity ingress and for sweet water recharge.

For regulating development activities, the coastal stretches within 500 meters of High Tide Line on the landward side are classified into four categories viz CRZ-I,II,III and IV. CRZ-I includes those areas, which are ecologically sensitive and important, which also includes mangroves. Areas between the Low Tide Line and High Tide Line also falls within CRZ-I. In this Zone no new construction is permitted within 500 meters of the High Tide Line. Between Low Tide Line and High Tide Line also no construction activity is permitted except those pertaining to facilities for carrying treated water discharge into the sea, facilities for carrying sea-water for cooling purposes, oil, gas etc. CRZ-II includes those areas, which have already been developed upto or close to the shoreline. CRZ-III includes those areas, which are relatively undisturbed and those, which do not belong to either CRZ-I or II. CRZ-IV includes coastal stretches in Andaman and Nicobar, Lakshadweep and small islands except those designated as CRZ-I, CRZ-II or CRZ-III.

Enforcement of the legislative mandates is a prime need (Untawale, 1992)

3. <u>Afforestation</u>

Mangrove afforestation is required for quick restoration of degraded mangrove areas and also to increase mangrove cover. Restoration of mangrove areas is the key aspect of mangrove management (Field, 1996). Large-scale mangrove afforestations have been taken up in Goa along Mandovi, Zuari, Chapora estuaries and Cumbarjua canal. However, in Andaman and Nicobar Islands, no large-scale mangrove afforestation works have been taken up in last three years. Nursery is an important component of mangrove afforestation programme. Plate-6.5 shows a view of the mangrove nursery at Shyamkund (Middle Andaman).

Plate-6.6 shows a view of successful attempt in restoration of degraded mangrove area through afforestation.

Mangrove afforestation in Florida (USA) is conducted in a legal context for ecological reasons relating to fisheries and wildlife. Horticultural practices such as pruning and trimming are also prohibited in mangrove areas irrespective of ownership. Although permits for mangroves destruction are approved when they in the public interest (Gilmore & Snedaker, 1993).

As a result of mangrove conservation as well as reforestation programme along the central West Coast of India, the following impacts have been observed:
Public awareness regarding importance of mangroves has increased, intertidal mudbanks and their establishment have been controlled, new avenues for forestry and social forestry activities have opened, biomass along the estuaries has increased, which has resulted in additional organic matter which has further influenced the biological productivity, bird and other animal life has increased (Untawale, 1996).

PLATE- 6.5

A view of Mangrove nursery at Shyamkund (Middle Andaman)

PLATE- 6.6

A successful attempt in restoration of degraded mangrove area through afforestation

4. Awareness programme

People's awareness regarding importance of mangroves is most essential for getting their willing support for effective conservation and management of mangroves. Awareness can be spared through film shows; exhibition; newspapers; magazines; distribution of posters, stickers and brochures; display of banners, organisation of seminars, nature camps, bird watching etc (Anonymous, 1997). "Mangrove Conservation Day" may also be celebrated to spread the awareness. On this day essay competition, debate, drawing competition etc. may be organised. School teachers may also be requested to conduct study tours in the mangrove forests to spread awareness among students. Establishment of Mangrove Parks in the mangrove areas close to towns may be a very powerful and effective medium to educate people especially children. The park may have facilities like Nature Education and Interpretation Centre, small library, boats for movement in the creeks, watch-towers, walk-ways etc.

Once the people realise the importance of mangrove ecosystem, they themselves come forward to protect and develop the ecosystem for their own benefit.

Tanzania mangals are in a stressed condition and degrading day by day, likewise the other mangals of the SE Asian countries. These need well-planned policy making alongwith strict conservation measures, awareness programmes and people's participation (Naskar & Mandal, 1999).

5. **People's involvement**

As far as possible local people should be involved in the mangrove conservation and development works. Local people's participation may involve information sharing, consultation, decision making and implementation of plans (FAO, 1994).

People residing close to mangrove forests, may prove very effective in the protection of the forests. They may be made responsible for protection and in return government may offer them fuelwood, small timber and other non- timber forest produce, for their own use, derived from the mangrove forests. They may also be engaged as casual labourers for raising mangrove nurseries, plantations and other works in order to give them employment and earn their goodwill. During the period of their employment, motivational efforts may bring active co-operation of the people in mangrove forest protection, spreading awareness and other miscellaneous works even after discontinuance of their employment with the government (personal experience).

The mangrove forests at Can Gio (Vietnam) are divided into 24 sectors with clear natural borders (Cuong, 1994) and presents a classic example of people's involvement in management of mangrove forest. The main guard force includes workers from the Management Board of the City's Environmentally Protected Forests (MBCEPE), workers from the agro-forestry enterprises, employee of the Forester Agency, and household allotted forests to protect. Local households have signed 30- year contract with MBCEPE. To date, a total area of 10,850 ha has been allotted to 208 household forests. The guards are given monthly salaries, 35% of the forest produce from thinning, an allocation of 3 to 5 ha per household for aquaculture or salt-pans and reward for good protection of forests. Other benefits that the households have obtained are: money to build houses on allotted land, boats for forest protection, loans for fisheries production in accordance with the common plan and schedule of the city, and technical help through short training courses on thinning, reforestation and shrimp forming. These measures have successfully educated the local people about the role of the mangrove ecosystem in providing direct and indirect benefits (Hong, 1996). In India, if the people are to be involved in mangrove management, similar type of measures will have to be taken, otherwise active participation of people may not be achieved.

6. Survey of mangroves

So far no systematic ground survey of mangrove has been done in Goa to find out precise area under mangroves and to ascertain their ownership. This survey is very necessary for proper planning and management of mangroves. The first step for preparation of management plan for any mangrove area is a fact-finding survey. Unless the state of mangroves is completely known, no plan for mangrove area can be prepared (Anonymous, 1989).

7. Management of mangroves occurring on the Private and Village community- Land

Mangroves on such type of lands may be conserved and developed with active co-operation of the owner of the land. Government may offer some benefits/ concessions to the owners of the land if they agree to conserve mangroves occurring on their lands. This requires detailed study and wide discussions on the subject matter before taking any action. The Government may also acquire some important mangroves bearing areas.

8. Planned Development

All the developmental activities in the State should be planned in such a way so as to be in harmony with mangroves conservation and development works.

Matang Mangroves have been often reported to be one of the best-managed mangroves in the world (Chan, 1996). The forest plantations through planned development are able to sustain ecological balance, forestry activities and also a wealth of fishing industries.

Ong (1978) estimated that the Matang forest industries involving extraction and processing of timber provide employment for a direct work-force of about 1400 and an indirect work-force of another 1000. The total annual revenue from forestry is about a million US dollar (Haron, 1981). The fishing industries, on the other hand, provide direct employment for about 2600 workers and indirect employment for about 7500 workers. Annual revenue derived from fisheries has been estimated to be about 33 million US dollars (Tang *et al.*, 1984). Thus, the 40,000 ha Matang Mangrove provides employment for a work-force of about 12,500 and annual revenue of about 42 million US dollars. On an area basis, this works out to a monitory return of just over 1000 US dollar per hectare. The coastal waters, estuaries and waterways of Matang support flourishing fishing industries while the extensive mudflats serve as feeding and stop over for both resident and migratory shore birds (Chan, 1996).

Recently, efforts have been made to promote eco-tourism. Facilities available include a museum, boat cruising and boardwalks. The success of management is reflected in the extent of quality forest stands which accounts for about 85% of total mangrove area in Matang (Chan, 1996).

9. <u>Infestation by Barnacles, Oysters, Crabs and Gastropods</u>

Nursery grown tall seedlings should be used for planting to reduce the infestations by barnacles as the leading shoot of tall seedlings remain above the water level. Taller seedlings are less vulnerable to attack by oysters, crabs and gastropods (personal observation).

Intensity of insect infestation is higher in mono-specific crop, which can be controlled by raising mixed plantations (Siddiqi *et al.,* 1992)

In Vietnam, planters apply sap of *Excoecaria agallocha* to the mangrove stem, which force the barnacles to leave the mangrove seedlings or die. Some people place chemical pesticides on a wet cloth and tap the bundle gently on the stems or roots of mangrove plants where oysters are clinging at ebb tide. After 10-20 minutes, the oysters leave the stand. However, these methods when applied can cause water pollution (Hong, 1994).

(10) Marine algae

To restrict the harm caused by algae, removal from the mud flat and from the seedlings is done manually at neap tide. Bent seedlings are strengthen and held up with the earth (Hong, 1996).

(11) Research Activities

To solve various problems, research work is necessary to find out their solution. Research is also needed to collect basic information required for appropriate management of mangrove ecosystem.

The Government of India, through the Ministry of Environment and Forests has set up a National Mangrove Committee to plan research and development programmes for Indian mangroves. At the state level, there are State Level Steering Committees, which look into mangrove programmes. Although during the last 5 years much activity has taken place in the field of mangrove management, there is an urgent need to determine priorities under this programme. Conservation, afforestation, and thorough ecological studies of denuded mangrove areas are of the utmost importance (Untawale, 1992).

Research activities should be scientifically designed. In Thailand, initially research programmes were not based on scientific designs and as a result during the last 20 years about 30% of the total mangroves have been destroyed (Aksornkoae, 1987).

In Malaysia, during 1978, an adhoc Mangrove Research Co-ordinating Committee with the leadership of the Malaysian Forest Research Institute was formed with the objectives to co-ordinate the different research activities of the Malaysian mangroves and to avoid duplication of works. Various institutes in Malaysia have taken up activities and studies in connection with the development, management and conservation of Malaysian mangroves. Some of the important studies are on the topics like natural regeneration of important mangrove species, effect of thinning on mangrove stands, phenological studies of economic mangrove tree species, impact of bunding on mangroves, mangrove restoration along eroding mangroves shores, natural succession following clear felling, planting trials of *Rhizophora* in *Avicennia* forests and *Acrostichum* infested areas, natural regeneration in exploited areas, growth of mangrove trees in natural and exploited forests etc. (Chan 1987).

6.2.2 Developmental Issues

Basically, mangrove areas are managed for three broad objectives viz. Preservation, Conservation and use of mangrove areas for various developmental purposes.

(a) Preservation

Under preservation absolute protection is provided to the area and we do not interfere at all with the natural processes. Ecologically unique and fragile mangroves may be preserved as "protected areas" not only to afford protection to endangered wild life and flora but also to maintain biodiversity.

(b) Conservation

Conservation is defined as "the management of human use of the biosphere (i.e. all living things) so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations" (FAO, 1994).

Conservation ensures maintenance, restoration, development and sustainable utilisation of the mangrove resources. Conservation gives a scope for various management practices like exploitation of timber and N.T.F.P.(Non Timber Forest Produce), afforestation, utilisation of other products from the mangrove ecosystems. It also talks about the mangrove areas which can be converted for taking various developmental activities in mangrove areas without adversely affecting mangroves in any way. The mangroves of Australia were not directly exploited. As such, the research programmes have been undertaken to investigate the pristine systems and the insights of the conservation and preservation. The mangroves in Australia are under proper conservation (Bunt, 1987).

(c) Use of mangrove areas for various economic purposes

Only those inter-tidal areas on the landward side, which are not suitable for the growth of mangroves, may be spared for various developmental activities such as large scale pond mariculture or agriculture etc.

Where land reclamation for industrial development is contemplated, the negative ecological effects and economic costs associated with the loss of natural coastal protection provided by the mangroves and the possible decrease in fishery revenues and other benefits should be evaluated. Before conversion is undertaken, an environmental impact assessment should be undertaken (FAO, 1994).

Untawale (1992) has expressed following opinion on utilisation of mangrove areas: The existing pristine mangrove forest should be considered either for preservation or for management. Open degraded areas, particularly beyond the supralittoral region, should be used for brackish water fish farming. The estuarine water fringing the mangroves can be considered for fishing, navigation, recreation (water sports) as well as for research and education. The marshy areas with high to very high soil salinity and low rainfall can be restored for salt production and *Artemia* (brine shrimp) culture. The open swampy areas with regular tidal flushing and silty clay soil are most suitable for mangrove afforestation. The mangrove areas which have already been converted to dry land are unfit for productive use, may be suitable for urban development, roads and industries.

Umali (1985) gave guidelines on the mangrove areas to be preserved, conserved, or declared as forest reserves (Table-6.2).

TABLE- 6.2

GUIDELINES FOR THE SELECTION OF MANGROVE AREAS FOR PRESERVATION, CONSERVATION, DECLARATION OF FOREST RESERVES AND RELEASE FOR AGRICULTURE/ AQUACULTURE USE

Location	Proposed action	Reasons
Adjoining major river systems.	Conserve	Maintenance of ecological balance
Adjacent to productive fishing zones.	Conserve	Ensure breeding, spawning and nursery-grounds of fish and prawns.
Adjacent to settlement.	Conserve and ensure scientific agro-forestry planning.	Ensure for continuous use of minor forest products through management.
Primary and dense forest growth regardless of location.	Preserve, declare as reserved.	Maintenance of ecological balance, use as wildlife sanctuaries and for research.
Places with significant hazards (pollution) if developed.	Preserve, take measures of protection.	Protection against erosion, floods, etc.
Around small islands.	Preserve, if possible ensure regeneration.	Maintenance of ecological balance and protection from erosion.
Others (exclusive of the above points.	May be studied for development	For agriculture, aqua-culture, salt formation or any other land use, whichever is most compatible.

SOURCE: Umali (1985)

In view of the multiple use potential of mangrove ecosystem, it is imperative that mangrove based terrestrial and aquatic resources be managed in an integrated manner. This implies that no single resource use should be maximised to the point where sustainable potential of another resource is adversely affected. Conservation and management of mangrove ecosystem forms an integral part of **Integrated Coastal Area Planning**. The mangrove swamp is closely linked to terrestrial land uses practices. Change in water flow regimes affect the mangroves and the overdrawing of ground-water or excessive removal of mangrove vegetation may increase the danger of aquifer salinisation and contamination. Consequently, the coastal zone is to be considered as an integral component of overall regional lands use planning and development so that appropriate land uses policies and action programmes may be formulated. Priority should be given not only towards the rehabilitation of degraded coastal lands but also the rational use of land on a sustainable basis, including the planned development of sustainable forests and marine products. Under Sustainable Utilisation single use option should be avoided because they sub-optimise the multiple use potential of mangrove ecosystems (FAO, 1994). Following developmental activities may be taken in mangrove areas:

A. Agriculture in Mangrove areas

At the best, reclaimed mangrove areas can be considered as marginal agricultural lands. Soils in mangrove areas are highly saline and potentially acid sulphate. Because of these two properties of the mangrove soils, it can be used for raising limited variety of crops and that too by giving special treatment to the soil. In mangrove areas, one must ensure adequate supply of water to maintain water table above the sulphide layer in the soil. This will prevent oxidation of sulphides present in mangrove soil, which may otherwise result in the formation of acid sulphate soils. Mangrove soil can be used for raising following crops: -

1. **Paddy cultivation**

Goa has around 18,500 ha of Khazan land (reclaimed mangrove land). Out of this about 2,000 ha is cultivated for two paddy crops in a year and about 12,500 ha is cultivated for single paddy crop and the remaining 4,000 ha is lying fallow/unused.

Potentially acid sulphate soil should be avoided for paddy cultivation. Soils, which do not require any reclamation, are preferred. Excessive clearing of the natural vegetation may be avoided. Fresh water supply must be ensured in adequate amounts and proven salt tolerant varieties of rice should be used. Rice cultivation became a major food crop in mangrove areas in Guinea and Sierra Leone around 1855 and much later in Madagascar (1935). In Myanmar, the colonial administration, who considered the luxuriant *Heritiera formes* forests to be wasteland, transformed the Ayeyarwady delta mangroves into paddy fields during 1852 (FAO, 1994).

Singh and Mongia (1987) recommended following management practices for paddy cultivation in the reclaimed mangrove areas

(a) Leaching to remove excess salts, soluble sulphates and iron.

(b) Liming to precipitate toxic aluminum, depress the concentration of dissolved iron, lower the concentration of hydrogen sulphide and increase the availability of phosphorous.

(c) Judicious application of phosphatic fertilizers and other nutrients.

(d) Use of salt resistant varieties.

Singh and Mongia (1987) obtained rice yield of 36.7 quintal per hectare from mangrove area.

2. Coconut Plantation

As the coconut is a salt tolerant plant, it is most preferred for planting on the reclaimed mangrove areas. It is a successful crop in Andaman and Nicobar Islands. Coconut has often been the first crop planted on reclaimed mangrove swamps, due to its salt tolerance. Yield is, however, affected by pH changes brought about by drainage especially in the potentially acid sulphate soils. Experimental trials showed that a drop in pH caused by drainage resulted in yields plummeting from 5154 to 2818 nuts/ha/yr (Zahari, 1983). Sometimes cocoa and banana have been successfully inter-cropped with coconut on acid sulphate soils, assisted by the application of limestone powder around the palm clumps (FAO, 1994).

3. Cultivation of *Nypa fruticans*

In Andaman and Nicobar Islands, *Nypa fruticans* (palm) is naturally found along the muddy creeks where there is regular and abundant supply of fresh water. Its leaves, fruits and stalk are used for obtaining juice for manufacture of sugar and alcohol. Its leaves are also used for thatching purpose and kernel of young fruit is edible. The *Nypa* in the Andaman and Nicobar Islands so far has not been put to any use except for thatching (Sahni, 1957). Plate-6.7 shows a natural patch of *Nypa fruticans* in Middle Andaman.

In Bangladesh and Philippines, commercial plantations of *Nypa fruticans* have been raised. *Nypa* thatching and roofing are the important cottage industry in Malaysia (Naskar & Mandal, 1999). *Nypa fruticans* is used mainly as thatch for roofing but can also produce a sugary syrup, alcohol and vinegar (FAO, 1994). According to Vannucci (1989), *Nypa* cultivation can produce alcohol about 15,000 litres/ ha/ year, sugar about 20 tons/ ha/ year and thatching leaves about 16,000 Pieces/ ha/ year.

4. Cultivation of Oil Palm

Oil palm plantation in Malaysia have been established by adopting appropriate management practices (Poon, 1983). They yield almost same as compared to the plantation on the normal soil. Proper water control system should be adopted to prevent formation of acid sulphate soil. Addition of lime to the soil can further improve the productivity.

PLATE- 6.7

A natural patch of *Nypa fruticans* in Middle Andaman

B. Fisheries in Mangrove Areas

Mangrove forests are the excellent breeding and resting ground for varieties of fishes, prawns, crabs etc. Decomposed mangrove leaves act as nutritious food for these aquatic animals. Local fishermen in the coastal areas earn their livelihood by catching fishes, prawns and crabs from the mangrove forests using nets and by other traditional methods.

Plate-6.8 shows a local fisherman looking for fishes in a creek in mangrove area at Chorao (Goa). During High tide, fishermen place the long nets along the banks of estuaries/creeks. As the water recedes beyond the nets during the low tide, they collect the fishes, crabs, prawn and other seafood animals, which are trapped, on the bank due to presence of nets. While talking to the fishermen at Yerrata (Middle Andaman), they informed that one fisherman earns Rs. 3,500 to 5,000 per month by fish catch in mangrove areas. They also informed that during the neap tide prawn catch is maximum and in crabs, quantity of flesh is maximum on New moon day and minimum on Full moon Day.

In Goa, excellent mangrove area adjacent to Dr. Salim Ali Bird Sanctuary at Chorao has been clear-felled for aquaculture. This type of activity should be totally stopped as it damages the mangrove ecosystem. There are about 41- aqua farming in Goa situated along the Chapora, Mandovi, Zuari and Sal estuaries.

PLATE- 6.8

A local fisherman looking for fishes in a creek in mangrove area at Chorao (Goa)

Hon'ble Supreme Court of India in its judgement delivered on 12 th December, 1996 had upheld that the prawn farming was neither related to waterfront nor directly needs a foreshore facility and hence it should be banned along the 6,000 kms. long Indian coast, as it would cause pollution and destruction to the environment.

The conflict between the exploitation of mangroves for human needs and for the development or construction of aquaculture farm for intensive or semi- intensive shrimp/prawn farming have turned acutely. But the conservation of the mangrove forest or ecosystem for sustainable yield of the forest and sustenance of mangroves and its adjacent coastal capture fisheries have turned very acutely in the South-East Asian countries, including Sundarbans (Naskar & Ghosh, 1989).

Ling (1977) reported that the brackish-water fish culture was an "old age practice" in the mangrove-reclaimed zones. Vast mangrove zones have degraded in Philippines, Malaysia, Thailand due to development of fish /prawn and shrimp aquaculture. All these mangrove degraded fisheries may not act as productive for long term (Macnae, 1968). Intensive prawn culture practices replace the mangroves, which must have very adverse environmental impact on the adjacent mangrove ecosystem (Gong *et al.*, 1985).

Ong (1982) has commented, "The mangrove is nature's own aquaculture system with a number of advantages. An artificial system enjoys relatively easier harvest and selection of particular species but the natural system is vastly more stable and less susceptible to disease and epidemics."

C. Development of Apiculture

Mangrove forests have substantial potential for production of honey and wax (FAO, 1994). Honeybees build honeycomb on the higher branches of the mangrove trees and collect nectar from the mangrove flowers. Government of West Bengal earns revenue of over rupees sixty lakhs per annum from apiculture in mangrove forests of Sunderbans. Apiculture can be promoted as cottage industry as it provides following benefits:

(a) Honey production is an additional nutritious and non- perishable food item for the local people.

(b) It creates opportunities for the self- employment and also generates work for the local carpenters who prepare bee-keeping equipment.

(c) It indirectly helps in increasing production of other crops through cross-pollination.

(d) Apiculture can be a source of additional income. It requires very little investment. It can be adopted by both the sexes i.e. male and female in the family. Work can be looked after by any female member of the family when the male members go outdoor for the work.

(e) It is an eco-friendly activity.

D. Salt production

Reclaimed mangrove areas can be developed for establishment of salt pans for salt production. This can be an additional source of income for the local people. Solar salt production is a traditional and important industry in many coastal dry and semi-dry regions. As a basic commodity salt is required in the human diet and in some industrial and agricultural applications. It is also used for preserving fish, beef, fruits and vegetables. In 1980, about 25% of the world's salt production of some 175.5 million tonnes were produced using solar energy (FAO, 1994).

For manufacture of salt, seawater is guided into and trapped in bunded ponds constructed on higher ground during spring tides. Upon evaporation the salinity in the evaporation ponds increases until salt crystals precipitate from the concentrated brine.

E. Sea-weed culture

China, Hongkong, Vietnam, Philippines, Taiwan, Japan and Korea are the Asian countries that consume large quantities of sea-weeds as food and also for medicine and cosmetic purposes (FAO, 1994).

F. Development of eco-tourism

Mangroves along the estuaries and creeks adorn the nature with a unique beauty. Mangrove forests are the potential areas for development of eco-tourism. Mangroves are the habitat for variety of reptiles, birds and aquatic animals. Crocodiles and snakes are commonly seen in mangrove areas. Common birds in the mangrove of Goa are Egrets, Stork, Kingfisher, Bramhany kite, Bramhany duck, Grey heron, Sea gulls, Fishing eagle, Sandpipers, Pintales, River twins and coots. Development of eco-tourism can be an answer for the increasing unemployment problem. Table-6.3 gives information on arrival of domestic and foreign tourists in Andaman and Nicobar Islands in different years.

TABLE-6.3

ARRIVAL OF DOMESTIC AND FOREIGN TOURISTS IN ANDAMAN AND NICOBAR ISLANDS

Year	Number of Domestic Tourists	Number of Foreign Tourists
1991-92	36631	1829
1992-93	30197	2131
1993-94	44396	2179
1994-95	55975	2821
1995-96	66316	6036

SOURCE: Basic Statistics, (1996), Andaman & Nicobar Administration

If proper facilities are provided, a large number of tourists would like to enjoy floral and faunal beauty of mangrove ecosystem. Even this will lead to inflow of more and more tourists and spread awareness about the mangroves. At present very limited facilities are available in Andaman and Nicobar for the tourists to enjoy beauty of mangrove ecosystem. Even in the state of Goa, which is considered as tourists paradise, no organised tours are conducted by the tourism department, however, some private parties organize conducted tours to mangrove areas of Chorao and Cumbarjua canal mainly for the foreign tourists and charge them exorbitantly. Activities that can be promoted in mangrove areas are natural trails, bird watching, nature photography, crocodile farms, fishing, canoeing and botanical studies etc.

Tourism accounts for one third of the trade in goods and services of developing countries and the World Tourism Organisation (WTO) projects that it will become the world's largest industry by the year 2000 (WTO, 1989). There were 390 million international tourists in 1988 who created 74 million jobs and produced 195 billion dollar in local and foreign receipts. Adventure travel, which includes eco-tourism commanded almost 10% of the market in 1989 and is increasing at the rate of 30% a year (FAO, 1994).

Eco-tourism potential can only be realised if the resource, on which it is based, is well protected. In turn, it can empower local communities, give them a sense of pride in their natural resources and heritage and control over their communities development. In sum, it has the potential to motivate rural population, maximise economic benefits and minimise environmental costs (FAO, 1994).

G. Crocodile rearing and breeding

Crocodiles require little space and care to rear. It has a low mortality rate and can be fed with cheap varieties of fishes. Successful crocodile rearing can bring radical changes in the socio-economic status of the people, however, it requires specialised training. Necessary clearance from the wildlife authorities of concerned country must be obtained before venturing in the business. Crocodile farms are boon to the Cambodians, who rear and breed crocodiles for their skin and meat.

Crocodile farming may be undertaken for commercial exploitation of its hide and meat and/ or as a way for improving the conservation of endangered species and for attracting eco-tourism. Cuba has organised crocodile farms that are opened for viewing by tourists (FAO, 1994).

H. Development of Drift wood and Carpentry Industry

Today, there is big demand for show-pieces made from driftwood and other small wood derived from the mangrove forests. These items fetch very high price in the national and international market. Realising the importance, Industries Department of Andaman and Nicobar has already started professional training for the local people in this trade.

CHAPTER-7

SUMMARY, CONCLUSION AND RECOMMENDATIONS

CHAPTER-7

SUMMARY, CONCLUSION AND RECOMMENDATIONS

The **Chapter-1** of the thesis is introductory in nature and *inter-alia* discusses the historical account of mangrove ecosystems, environmental and economic significance of mangrove ecosystem, environmental factors responsible for growth and distribution of mangroves, geographical distribution of mangroves, area under mangroves and species diversity in mangroves. The Chapter further discusses mangrove conservation and management scenario around the globe with special reference to India. At the end of the chapter justification of the problem has been discussed.

Increasing human pressure on the limited mangrove resources due to increase in population, increasing awareness regarding environmental and economical uses of mangroves highlighted the need for mangrove conservation and management. For preparing appropriate and effective management plan, basic data and information are required.

The **Chapter-2** discusses mangroves of Goa. Goa has 120 kms long coastline and mangroves occur along seven estuaries (Terekhol, Chapora, Mandovi, Zuari, Sal, Talpona, Galgibag) and Cumbarjua Canal. Introduction part of the chapter deals with the general description, coastal geomorphology, climatology, hydrology, tidal amplitude and edaphic factors of Goa State. The Chapter deals with the several studies conducted in State of Goa like distribution of mangroves along different estuaries/ canal, zonation in mangroves, status of natural regeneration of mangrove species in Goa. Conservation and management of mangroves of Goa have also been discussed in the chapter.

Detailed information on distribution of mangroves based on ground truthing is one of the most important and crucial data required for drawing management plan for effective conservation of mangrove ecosystem. This information enables us to adopt appropriate strategy and action plan not only for the conservation but also for the development of the mangrove ecosystem. Based on the field realties, artificial regeneration of mangroves can be taken up on various degraded sites for its quick restoration. Timely action can also be taken to multiply those species which are threatened or on the verge of extinction. Wherever feasible new mangrove species can be introduced after experimental trials in order to enrich the area. In addition to several other utilities, the information on distribution of mangroves can play a significant role in proper planning for safe and sustainable utilisation of mangrove resources.

The **Chapter-3** discusses the mangroves of Andaman and Nicobar Islands with special reference to the case study of Middle Andaman. Introduction part of the chapter deals with the general description, geology & geomorphology, climatology and hydrology of the Andaman and Nicobar Islands. The chapter *inter alia* deals with the several studies conducted within the territorial jurisdiction of Middle Andaman Forest Division namely, distribution of mangrove species in Middle Andaman Forest Division, their relative abundance, zonation in mangroves, status of natural regeneration of mangrove species in Middle Andaman Forest Division, assessment of total mangrove area in Middle Andaman Forest Division and its comparison with earlier reports and government records, assessment of exploitable growing stock, exploitable level, stand structure and utilisation of mangroves. The chapter also contains critical review of various mangrove conservation and management strategies in Middle Andaman Forest Division.

On the basis of the present study total mangrove area under Middle Andaman Forest Division was calculated at 13,006 hectares. Average exploitable growing stock was calculated at 163.53 cubic meter per hectare. Results obtained have been discussed in the thesis.

The **Chapter-4** deals with the information on characteristics of flowering, fruiting and germination of various species of mangroves. The chapter further deals with various topics, which were studied, namely, flowering and fruiting periods in Goa and Middle Andaman; characteristics of fruits, seeds and propagules of mangroves; propagules producing mangroves and characteristics of mature propagules; fruit producing mangroves and characteristics of mature fruits and seeds; germination period; germination percentage and survival rate for various mangrove species.

The information collected is necessary to plan timely collection of seeds, fruits, propagules for raising successful nurseries and plantations. Moreover, information on fruiting period is significant for planning strategy against illegal collection of mangrove fruits.

Introduction part of the **Chapter-5** focuses on needs and general objectives of artificial regeneration. The chapter concentrates on various aspects for establishment of mangrove nursery of various species and plantations of different species. Extensive practical work on raising mangrove nurseries and plantations was done in State of Goa and experimental nursery as well as plantation works were carried out in Middle Andaman. Results obtained have been discussed in the thesis.

Artificial regeneration of mangroves, has several advantages such as production of genetically superior stock, species selection as per choice and requirement, and above all degraded areas can be quickly restored by artificial regeneration. The major objectives are to check soil erosion; enhancement of natural regeneration in future; production of fuel, fodder and timber; effective utilization of barren and unused land to increase area under mangroves to derive maximum direct and indirect benefits; beautification of area; improvement of habitat; to support fisheries apiculture etc.

The **Chapter-6** deals with the conservation and management of mangrove ecosystem. Need for conservation and management of mangrove ecosystem is strongly felt primarily due to increasing human population, which is putting more pressures on mangroves. Growing awareness of the protective, productive and socio-economic function of the mangrove eco-system and consequences of their deterioration have also highlighted need for conservation and management of mangrove ecosystem. Conservation of mangroves is needed for maintaining healthy environment and sustained supply of timber, fuelwood, fodder and other non-timber forest produce (N.T.F.P.) to the local people living close to mangrove forests. Mangrove ecosystem can open many new avenues for self-employment like eco-tourism, fishing, honey bee keeping, mangrove forest produce based cottage industries etc for the local unemployed people, thereby, playing a crucial role in the socio-economic upliftment of the local communities.

Regulatory and Developmental issues related to mangrove management have been described in the chapter which are based on the field observations in Goa and Middle Andaman. Regulatory issues include illegal tree felling and lopping, indiscriminate conversion, discharge of industrial pollutants, encroachments, management of mangroves on private lands, cattle pressure, pests etc. Root causes of these problems and action-points to overcome these problems have been discussed in this chapter. Developmental issues in mangrove management include preservation, conservation and use of mangrove areas for various economic activities. Under preservation absolute protection is provided to the area and we do not interfere at all with the natural processes. On the other hand Conservation ensures maintenance, restoration, development and sustainable utilisation of the mangrove resources. Conservation gives a scope for various management practices like exploitation of timber and other N.T.F.P., afforestation, utilisation of other products from the mangrove ecosystems. Economic activities in mangrove areas include agriculture, fisheries, apiculture, salt production, eco-tourism, crocodile breeding and rearing, development of mangrove-wood based drift wood and carpentry industry etc. which have been discussed in this chapter.

Mangrove ecosystem has a great environmental and ecological significance and at the same time it also has strong economic potential, which is by and large under-utilised.

Significance of mangrove ecosystem and information on the allied subjects as described in the thesis clearly point out towards the urgent need for conservation and management of mangrove ecosystem on scientific lines in the interest of the mankind. Therefore, the subject matter should be given due importance by the government and all other concerned.

Although various points for ensuring better conservation and management of mangroves have been discussed in various chapters of the thesis, however, main points in the form of **recommendations** are as follows:

1) Un-wise biotic interference in mangrove areas should be checked to arrest degradation, facilitate natural regeneration and further growth of mangroves.

2) Mangrove protection measures should be strengthened and mangrove nursery and plantation works should be carried out with the active involvement of the local communities.

3) Offenders should be dealt very strictly under the law so as to have its deterrent effect.

4) New and useful mangrove species should be introduced in a particular area after conducting experimental trials.

5) Special efforts should be made to multiply rare mangrove species by raising nurseries, plantations and promoting their natural regeneration to save them from extinction.

6) Endangered mangrove species should be declared as “Protected species” to offer better protection status to them.

7) Wherever necessary, canopy should be carefully opened to minimum required extent so that Sun light may reach the ground and promote natural regeneration.

8) Andaman and Nicobar Forest Department should prepare a comprehensive mangrove management plan for restoration of degraded mangrove areas, people's education and awareness, mangrove research, inter-departmental co-operation etc. and implement it.

9) Andaman and Nicobar Forest Department should also give special emphasis on proper implementation of the existing Working Plan prescriptions for mangroves.

10) Andaman and Nicobar Forest Department should have necessary "Acts and Rules" to stop felling of mangrove trees in the government revenue and private areas.

11) As far as survey of mangroves is concerned, ground truthing must be done in addition to aerial survey to ascertain correct area under mangroves.

12) There is need for upgrading/ developing nursery and plantation techniques for those species whose artificial regeneration has not been tried commonly and extensively.

13) Area specific problems (like pest/ insect attack, etc.) in raising mangrove nursery and plantation should be studied in detail to find out their solution.

14) Government should promote and support traditional and improved sources of energy like LPG, Kerosene, improved chullas, solar cookers etc. in remote villages to reduce dependence of people on mangrove fuelwood.

15) Fodder yielding mangrove species should be raised preferably near the villages to solve problem of fodder.

16) Suitable legislation should be enacted for conservation and management of mangrove occurring on the private lands.

17) Poorly managed and under-utilised mangrove areas should be scientifically managed to ensure optimum land use from environmental and economic angles.

18) Artificial regeneration should be taken up in degraded mangrove areas, wherever feasible, for its quick restoration. Reasons for degradation of the area should be studied, analysed and their non-repetition should be ensured.

19) Specialized training should be imparted to officers and staff of Forest Department for better conservation and management of mangroves.

20) Research work on mangroves should be promoted for better resource management and utilisation. Inter organizational cooperation among various organizations working on the subject should be promoted for exchange of ideas, information etc.

21) To oversee implementation of Mangrove Management Plan, government should assign this job to competent and genuinely interested officers and staff and frequent transfers of such officials should be avoided.

22) Top level officers of the government should be sensitised about the importance and need of conservation and management of mangrove ecosystem so as to mobilize their active support for the programme.

23) Government should take initiative and provide necessary support to the genuinely interested individuals, reputed NGOs and private agencies etc. to build

strong data-base for management of mangrove forests on sound footings. The government should also strengthen its own organisations working in this direction.

24) Information available on mangrove ecosystem should be compiled at one place preferably by the Forest Department, so that it can be readily referred by all people concerned with the conservation and management of mangrove ecosystem.

25) To lift socio-economic status of the local people, economic potential of the mangrove ecosystem should be scientifically tapped without endangering the ecosystem from environmental and ecological angles.

26) Mangrove management should be a special component of all Watershed Projects involving mangrove areas.

27) In order to attract talents, to motivate and encourage the scientists and managers etc. to work in the field of mangroves, their good works should be suitably recognised and rewarded.

28) Mangrove education and awareness programmes should be seriously launched.

29) Community Forest Management involving local communities should be encouraged. Key role from people's side should be assigned to those residing close to mangrove areas.

30) Virgin mangrove areas should be identified and preserved for research and bio-diversity conservation as national park, sanctuaries, biosphere reserve etc.

31) Permanent preservation plots should be laid out in all the obvious stages of mangrove succession for study and research purposes.

32) Areas with good mangrove growth under the ownership of various government departments should be transferred to the Forest Department for conservation and management.

33) Ban imposed by the Government of India during 1986 on felling of mangrove trees should be reviewed now by conducting scientific studies on the present condition of mangrove forests. Wherever feasible extraction of mangrove timber, fuelwood, poles etc. may be done on safe and sustainable basis to fulfill genuine demand of the people.

REFERENCES

REFERENCES

Agaloos, B.D., (1994). Re-afforestation of mangrove forests in the Republic of the Philippines. In: Proceedings of the Workshop on ITTO project: *Development and Dissemination of Re-afforestation Techniques of Mangrove Forests*. 18-20 April, 1991, Bangkok, Thailand ITTO, JAM, Thai NATMANCOM/ NRCT: 84-86.

Agate, A.D., 1991. Mangroves microbiology. *Proc. Symp. Significance of mangroves,* (eds.) Agate, A.D., S.D. Bonde and K.P.N. Kumaran, Pune, India. Maharashtra Assoc. Cultiv. Sci. Res. Inst., 11-13.

Aksornkoae, S., (1985). Traditional uses of the mangroves in Thailand. In: (eds.) C.D. Field and A.J. Darnall, Mangrove Ecosystem of Asia and the Pacific, Status, Exploitation and Management, pp.104--113.

Aksornkoae, S., (1987). Country Reports: Thailand: *In: Mangroves of Asia and the Pacific: Status and Management.* Technical Report of UNDP/UNESCO Research and Training Pilot Programme on Mangrove Ecosystem in Asia and the Pacific (RAS/79/002). pp. 231-261.

Aksornkoae, S., (1996). Reforestation of mangrove forests in Thailand: a case study of Pattani Province. The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp. 59-62.

Ali, A., (1974). Instrction Manual for planting on Coastal Area. Departmental Instruction Manual, Bangladesh Forest Department. pp. 5-10.

Anand Rao, T., P.V. Suresh and A.N.Serieff, (1986). *Land Forms and Classification of Tidal Wetlands of the Karnataka coast,* Vols. I&II, Karnataka Asso. Advancement of Sci., Bangalore, India, pp. 225.

Anonymous, (1948 -1976). Wealth of India (Raw materials). Vol. 1 to XI. Pub. Infor. Dir. (CSIR). New Delhi.

Anonymous, (1952). Tropical silviculture. FAO, Vol. 1.

Anonymous, (1973). *International Classification and mapping of Vegetation.* UNESCO, Paris.

Anonymous, (1973). Fishery Resources of Hooghly-Matlah Estuarine System, CIFRI (ICAR) Bulletin 19, Barrackpore, West Bengal.

Anonymous. (1981 a). Tropical Forest Resources Assessment Project: Forest Resources of Tropical America. UN 32/6. 1301-78-04. Technical Report 1. FAO, Rome.

Anonymous. (1981 b). Tropical Forest Resources Assessment Project: Forest Resources of Tropical Africa. UN 32/6. 1301-78-04. Technical Report 2. FAO, Rome.

Anonymous. (1981 c). Tropical Forest Resources Assessment Project: Forest Resources of Tropical Asia. UN 32/6. 1301-78-04. Technical Report 3. FAO, Rome.

Anonymous. (1982). Management and utilization of mangroves in Asia and the Pacific; based on the work of Christensen, B. Environ. FAO, Paper 3. pp.160

Anonymous, (1983). *Global Status of Mangrove Ecosystems*. Commission on Ecology papers No. 3 (P. Saenger, E.J. Hegerl and J.D.S. Davie, eds.). International Union for Conservation of Nature and Natural Resources, Gland, Switzerland, pp. 88.

Anonymous, (1985). *Mangrove Management in Thiland, Malaysia and Indonesia,* FAO Environment. Paper No. 4, Rome.

Anonymous, (1987). *Mangrove in India-Status report. Govt. of India*, Ministry of Environment and Forests, New Delhi. pp. 52-55.

Anonymous, (1987). *Rapid Assessment Survey of the Industrial Pollution in Korangi-Phitti Creek*, Pakistan. IUCN. pp.2-6.

Anonymous, (1988). World-wide compendium of mangrove-associated aquatic species of economic importance. FAO Fish. No. 814 (FIRI/C814). pp.236.

Anonymous, (1989). Conservation of Mangroves in India, Government of India, Ministry of Environment and Forests, New Delhi. pp 24-55.

Anonymous, (1991). Mangrove Management Plan for Goa. *Report of Research and Utilisation Division*, Forest Department, Goa. pp 1-21 (Unpublished)

Anonymous, (1991). Mangrove Management and Action Plan of Maharashtra (for 1992-96) prepared by Mangrove Steering Committee, Govt of Maharashtra, Bombay, India, pp. 1-73.

Anonymous, (1991). Statistical Pocket Book of Goa. (1991-93). Directorate of Planning , Statistics and Evaluation, Government of Goa. Panaji. pp. LXIX, 1-2.

Anonymous, (1992). SAC (Space Application Centre), *Coastal Environment*, Remote Sensing Application Mission, (RSAM/SAC/COM/SN/11/92), ISRO, Ahmedabad, India, pp. 1-114.

Anonymous, (1994). Mangrove forests management guidelines, FAO, pp. 46, 169-191.

Anonymous, (1995). State of Forest Report. Forest Survey of India. Govt. of India, pp. 90.

Anonymous, (1996). Basic Statistics, Directorate of Economics and Statistics, Andaman and Nicobar Administration, Port Blair, **10**:14-47.

Anonymous, (1997). State of Forest Report. Forest Survey of India. Govt. of India, pp. 5-6, 38.

Anonymous, (1997). Management Plan for Conservation of Mangrove in Andaman and Nicobar Islands, Environment & Forest Department, A & N Administration, pp. 1-6.

Anonymous, (1999). Indian Tide Tables-Part-1, Geodetics and Research Branch Survey of India, Dehra Dun, pp. 230.

Anthony, M.K.D., V.N. Panakalaro & Sarkaranarayana, (1974). Studies on the monsoonal flow of the Mandovi Estuary. *Mahasagar Bull. Natn. Inst. Oceanography.* 7: 69-72.

Auberville, A., (1970). Vocabulaire de biogeographic appliqes aux regions tropicales. *Addisonia* **4**: 439-497.

Bagla, P. and S. Menon, (eds.). (1989). Ravaged forests and soiled seas: Ecological issues in the tropics with special reference to Andaman and Nicobar Islands, Kalpavrish, New Delhi.

Balachandra, L., (1988). A comprehensive account of the mangrove vegetation of Andaman and Nicobar Islands. *Indian For.* **114**: 741-751.

Balakrishnan, N.P., (1989). Andaman islands- Vegetation and floristics. *In: Andaman, Nicobar and Lakshadweep- An Environmental Impact Assessment*, C.J. Saldanha (ed.) C.J. Saldanha. Oxford and IBH publishing Co., Pvt. Ltd., New Delhi pp. 55-68.

Bandyopadhyay, A.K., (1992). Role of mangroves in Island Ecosystems with particular reference to the Bay Islands. *In :Proceedings of the Project Formulation Workshop for establishing a Global Network of Mangrove. Genetic Resource Centres for Adoption to Sea Level Rise,* (eds.). S. V. Deshmukh & R. Mahalingam Padroo. pp. 15-19.

Banerjee, J., (1954). Forestry in Andaman and Nicobar Islands. *Indian For*. **80**: 746.

Banerjee, J., (1957). Regeneration and exploitation of Mangroves, In: "*Mangrove Symposium*", Calcutta, pp. 124 - 128.

Banerjee, J., (1958). The mangrove forests of Andamans. *Wld. For. Congr.* : 425-430.

Banerjee, L.K., A.R.K. Sastry & M.P. Nayar, (1989). Mangroves in India, *Identification Manual,* Botanical Survey of India, Calcutta, pp. 5-12.

Banerjee, L.K. and D. Gosh, (1998). Species diversity and distribution of mangroves in India, Botanical Survey of India. An anthology of Indian Mangroves, ENVIS Publication. New Delhi, pp 22-24.

Basha, S.C., (1991). Distribution of mangroves in Kerala. *Indian. For.* **117**(6): 439-448.

Basu, B.K., (1994). Working Plan of Middle Andaman Forest Division. (1993-2003), Andaman and Nicobar Forest Administration, Port Blair. pp. 1-14.

Blasco, F., (1975). The Mangroves in India, (translated by K. Thanikaimoni from *Les Mangroves De L'inde*). Institute Francais de Pondicherry, Inde, Sri Aurobindo Ashram, India, **1**:1-175.

Blasco, F., (1977). Outlines of ecology, botany and forestry of mangroves of Indian subcontinent. *In: Ecosystem of the World: Wet Coastal Ecosystems.* V.J. Chapman (ed.) Elsevier Scientific Publ. Co. Amsterdam. New York, **1**:241-260.

Blasco, F., (1984). Climatic factors and the biology of mangrove plants. In: The mangrove ecosystem: Research methods. (eds.) S.C. Snedaker and J.G. Snedaker, UNESCO. pp. 81-90.

Blatter, E., (1905). The Mangroves of Bombay Presidency and its Biology. *J. Bombay Nat. Hist. Soc.* **16**: 644-656.

Bunt, J.S., W.T. Williams and J.H. Clay, (1982). River water salinity and the distribution of mangrove species along several rivers in North Queensland. *Aust. J. Bot.* **30**:401-412.

Bunt, J.S., (1987). *Australia, Country Reports*: Mangroves of Asia and the Pacific: Status and Management, Technical Report of the UNDP/ UNESCO Research and Training Pilot Programmes on Mangrove Ecosystems in Asia and the Pacific (RAS/79/002), pp. 263-280.

Cabahug. D.M. Jr., F.M. Ambi, S.O. Nisperos and N.C. Truzan Jr., (1986). Impact of community based mangrove forestation to mangrove dependent families and to nearby coastal areas in central Visayas. A case example. *In*: *Mangroves of Asia and the Pacific: Status and Management:* RAS/ 79/002- UNESCO/UNDP: 461-463.

Carter, J., (1959). Mangrove succession and coastal changes in S.W. Malaya. *Trans Inst. Brit. Geogr.* **26**: 79-88.

Chai, P.K., (1982). *Status and strategy for the management and utilisation of Mangrove Forests in Sarawak.* Forest Department, Malaysia (Unpublished report).

Champion, H.G., (1936). A Preliminary Survey of the Forest Types of India and Burma. *Indian For. Rec* (N.S.) **1**(1): 286. *

Chan, H.T., (1988). Rehabilitation of logged over mangrove areas using wildings of *Rhizophora apiculata. Journal of Tropical Forest Science* **1**(2): 87-188.

Chan, H.T., (1990). Proposal establishment and management of mangrove planting in the Duyen Hai District, South Vietnam. *FAO Field Doc.* NATVIE/86/027: 13-15.

Chan, H.T., (1994). Re-afforestation of mangrove forests in peninsular Malaysia. In: Proceedings of the Workshop on ITTO project: *Development and Dissemination of Re-afforestation Techniques of Mangrove Forests.* 18-20 April, 1994. Bangkok, Thailand ITTO, JAM, Thai NATMAN / COM NRCT: 117-122.

Chan, H.T., (1996). Mangrove reforestation in Peninsular Malaysia: a case study of Matang. The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp. 64-75.

Chanda, S., (1977). An-ecofloristic survey of the mangrove of Sundarbans, West Bengal, India. *Trans. Bose Res. Inst.* **40** (1): 5-14.

Chapman V.J., (1970). Mangrove phytosociology, *Trop. Ecol.* **11**: 1-19.

Chapman, V.J., (1976). *Mangrove Vegetation.* Vaduz: J.Cramer, pp. 447.

Chapman, V.J., (1977). *Ecosystem of the World: Wet Coastal Ecosystems,* Elsevier, New York. **1**:428.

Chatterjee, D., (1957). The nature and distribution of the mangrove plants. *Proc. Mangrove Symposium.* Ministry of Food and Agri., Calcutta, pp. 132-134.

Chengappa, B.S., (1944). Andaman forests and their regeneration-I. *Indian For.*, **70** (9): 207-304; 339-351.

Chopra, R.N., S.L Nayar, and I.C. Chopra, (1956). *Glossary of Indian Medicinal Plants,* CSIR, New Delhi.

Christensen, B. and S. Wium-Andersen, (1977). Seasonal growth of mangrove trees in southern Thailand I. Phenology of *Rhizophora apiculata* Bl. *Aquat. Bot.*, **3**:281-286.

Clarke, C.B., (1896). Presidential address to the Linnean Society on the Sunderbans of Bengal. *Proc. Linn. Soc., London.* **32**: 14-29.

Clarke L.D. and N.J. Hannon, (1967). The mangrove swamp and salt marsh, communities of the Sydney district. I. Vegetation, soil and climate. *J. Ecol.* **55**: 753-771.

Clough, B.F., (1982). Growth and salt balance of the mangroves, *Avicennia marina* (Forsk) Vierh. and *Rhizophora stylosa* Griff. in relation to salinity. *Aust. J. Plant Physiol.*, **11**: 419-430.

Clough, B.F. and P.M. Attiwill, (1975). Nutrient cycling in a community of *Avicennia marina* in a temperate region of Australia. *In: Proceedings of the International Symposium on Biology and Management of Mangroves* (eds.) G.E. Walsh, S.C. Snedaker, and H.J. Teas, **1**: 137-146.

Cooke,T., (1908). *The Flora of the Presidency of Bombay.* (ed.). Taylz and Francis, London.

Cornwell, R.B., (1937). Working Plan for Godavari Lower Division. (1934-1944) Forest Dept, Andhara Pradesh.

Curtis, S.J., (1933). *Working Plans for the Sunderbans Divisions*, Bengal, India, for the period from 1st April 1931 to 31st March 1951. Vol I-II, Govt. of West Bengal, Calcutta.

Dagar, J.C., (1982). Some ecological aspects of mangrove vegetation of the Andaman and Nicobar Islands in India. *Sylvatrop Philipp. For. Res. J.*, **7**: 177-216.

Dagar, J.C., (1987). Mangrove vegetation, its structure ecology, management and importance with special reference to Andaman and Nicobar Islands. *In: Proc. Symp. Management of Coastal Ecosystems and Oceanic Resources of the Andamans* 17-18 July, 1987, Andaman Science Association (CARI), Port Blair. pp. 8-23.

Dagar, H.S., (1989). Plant folk medicines among Nicobarese tribals of Car Nicobar Island, India. *Econ. Bot.* **43** (2): 215-224.

Dagar, J.C., and H.S. Dagar, (1986). Mangroves and some coastal plants in ethnobotany of the tribals of Andaman and Nicobar Islands. *J. Andaman Sci. Assoc.* **2** (2): 33-36.

Dagar J.C., A.D. Mongia. and A.K. Bandyopadhy, (1991). *Mangroves of Andaman and Nicobar Islands*, Oxford & IBH Publishers, New Delhi, pp 99-102 and 138-156.

Dagar, J.C. and N.T. Singh, (1999). Plant Resources of the Andaman and Nicobar Islands, M/S Bishen Singh Mahendra Pal Singh, Dehra Dun, pp. 67-94.

Das, S. and N.A. Siddiqi, (1985). The Mangrove and Mangrove Forests of Bangladesh. Mangrove Silviculture Division Bulletin No. 2. Bangladesh Forest. Research Institute and UNDP/FAO Project BGD/79/017. Chittagong, Bangladesh. pp. 1-12.

Das, A.K., and M.K. Dev Roy, (1989). *A General Account of the Mangrove Fauna of Andaman and Nicobar Islands.* Fauna of conservation areas: 4, Zoological Survey of India, **17**: 173.

Davies, J.H.Jr., (1940). The Ecology and Geologic role of mangroves in Florida. *Pap. Tortugas Lab.*, **32**: 303-412.

Dawes, C.J., (1981). *Marine Biology*. John Wiley & Sons, New York.

Deshmukh, S.V., (1991). Description of the site selected for the mangrove genetic resource centre. (eds.) S.V. Deshmukh, R. Mahalingam, A Global Network of Mangrove Genetic Resource Centres project Formulation Workshop, Madras, India, pp.99-106.

Deshmukhh, S.V and S. M. Karmarkar, (1990). Plantation of mangroves in disturbed habitats of Maharashtra. *In*: *Proceedings Symposium on the Significance of Mangroves*, (eds.) A.D. Agate, S.D. Bonde and K.P.N. Kumaran Pune, India. pp. 24-30.

Duke, N.C., (1992). Mangrove floristics and biogeography, (eds.). A.I. Robertson, and D..M. Alongi (eds.). *In: Tropical mangrove ecosystem*. S. 101-136. Coastal and Estuarine studies, 41, American Geophysical Union, Washington D.C., pp. `63-100.

Dwivedi, S.N., A.H. Parulekar, S.C. Goswami, and A.G. Untawale, (1974). Ecology of mangrove swamp on the Mandovi Estuary, Goa, India. In: Walsh, G.E., Snedaker, S.C. and Teas, H.J., Eds. Proc. of the Intl. Symp. On Biol. and Mgmt. of Mangroves., Florida, Univ. of Florida, pp. 115-125.

Ellis, J.L., (1987). Floral composition of the nearshore vegetation of the Andamans. *Proc. of the Symp. On Management of coastal Ecosystems and Oceanic Resources of the Andamans*, (eds.) N.T. Singh, B. Gangwar, G.C. Rao, and R. Soundararajan, pp. 24-27.

Ermenko, N.A. & V.V. Sastri, (1977). On the Petroleum Geology of Andaman Islands. *Bull. ONGC*, **14** (1,2); 35-47.

Field, C., (1996). General Guidelines for the Restoration of Mangrove Ecosystems, *In*: *Restoration of Mangrove Ecosystems*, The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp.233-250.

Fradin, D., (1985). The mangrove ecosystem in Papua New Guinea, (eds.). C.D. Field, A.J. Dartnell, *In: Mangrove ecosystems of Asia and the Pacific, Townsville, Australia.* pp.53-63.

Genkel P.A.K., (1962). *Zhur. Biol.*, (Transl.) 7V: 151.

Getter, C,D., G. Cintron, B. Dicks, R.R. Lewis and E.D. Seneca, (1984). The recovery and restoration of salt marshes and mangroves following an oil spill, pp. 65-114. *In*: *Restoration of Habitats Impacted by Oil Spills*, (eds.) J. Cairns and A. T. Buikema. Butterworth Publ., Bosto. MA. USA, pp. 182.

Gill A.M., (1975). Australia's mangrove enclaves. A coastal resource. *Proc. Ecol. Soc. of Australia*, **8**: 129-146.

Gilmore, R.G. and S.C. Snedaker, (1993). Mangrove forests. *In*: *Biodiversity of the Southeastern United States: Lowland Terrestrial Communities.* (eds.) W.H. Martin, S. Boyce and K. Echtenacht. John Wiley and Sons, New York. pp. 165-198.

Gocke, K., M. Vitola, and G. Rojas. (1981). Oxygen consumption in a mangrove swamp on the Pacific coast of Costa Rica, *Revista de Biologia* Tropical **29**(1): 143-155.

Gomes, H.R. & S. Mavinkutvi, (1982). Studies on Mangrove Swamps of Goa. II. Micro-organisms degrading phenolic compounds. *Mahasagar Bull. Nat. Inst. Oceanogr.* **15** (2): 11-115.

Gong, W.E., J.E. Ong, and C,H, Ong, (1985). The different uses of mangroves and their possible impacts on mangroves and adjacent coastal fisheries. In: *Proc. MAB/COMAR Regional Seminar Man's Impact on Coastal and Estuarine Ecosystems*, (eds.) T. Saeki, A. Hino, T. Hirose, M. Sakomoto & K. Ruddle. November 1984, Tokyo, MAB Co-ordinating Committee of Japan. pp. 21-26.

Gopal, B. and K. Krishnamurthy, (1993). Wetlands of South Asia. *In: Wetlands of the world I: Handbook of vegetation science. Inventory, ecology and management* (eds.) Whigham, D.F., D. Dykyjova and S. Hejny, pp.345-414.

Government of Goa, Forest Department, Notification No. 8/10/83/FOR dated 16.1.88.

Government of Goa, Forest Department, Notification No. 2-22-74-FOR (C) dated 28.4.88.

Government of Goa, Forest Department, Notification No. 8-10-83/FOR dated 16.12.88.

Government of Goa, Forest Department, Order No. 8/10/83/FOR dated 16.7.90.

Government of Goa, Urban Development Department, Letter No. 4-3-4-90-UDD dated 14.9.90.

Government of Goa, Forest Department, Notification No. 8/10/83-FOR dated 11.9.90.

Griffth, W., (1836). On the Family of Rhizophoraceae, *Trans. Linn.. Soc., Calcutta*, **8**: !5.

Hamilton, L.S., and S.C. Snedaker, (1984). (eds). Restoration and Establishment. Section 111. *In: Handbook for Mangrove Management.*, IUCN-UNESCO-UNDP-EWC Hawaii, pp. 102-108.

Haron, A.H., (1981). A Working Plan for the Matang Mangrove, Perak, 1980-89. *Perak State Forestry Department Publication.*

Heald, E.J., and W.E. Odum, (1970). The contribution of Mangroves swamps to Florida fisheries. *Proceed. Of the Gulf and Caribbean Fisheries Inst.* **22**: 130-135.

Hong, P.N., (1994). Re-afforestation of mangrove forests in Vietnam. In: Proceedings of the Workshop on ITTO project: *Development and Dissemination of Re-afforestation Techniques of Mangrove Forests.* 18-20 April 1994. Bangkok, Thailand ITTO, JAM, Thai NATMAN / COM NRCT: 141-151.

Hong, P.N., (1996). Restoration of mangrove ecosystems in Vietnam: a case study of Can Gio District, Ho Chi Minh City. The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp. 82-95.

Hooker, J.D., (1872). *Flora British India*, Vols. I-VII. BSI, India.

Hosokawa, T., H. Tagawa and V.J. Chapman, (1977). Mangals of Micronesia, Taiwan, Japan, the Philippines and Oceania. (ed.). V.J. Chapman (ed.). *Ecosystems of the World*: Wet Coastal Ecosystems, Vol.II. Elsevier, New York.

Htay, U. Aung San., (1994). Re-afforestation of mangrove forests in Myanmar. In: Proceedings of the Workshop on ITTO project: *Development and Dissemination of Re-afforestation Techniques of Mangrove Forests*. 18-20 April 1994. Bangkok, Thailand ITTO, JAM, Thai NATMAN / COM NRCT: 171.

Jagtap, T.G., (1985a). Studies on littoral flora of Andaman Islands. *Marine Plants*. Papers presented at the *All India Symposium on Marine Plants; their biology, chemistry and utilization*, Donapaula, Goa. Oct. 30-Nov, (eds.) V. Krishnamurthy & A.G. Untawale, 1985, pp. 73-78.

Jagtap, T.G., (1985b). Studies on littoral flora of Andaman Islands. *In*: *Marine Plants*, (eds.), V. Krishnamurthy & A.G. Untawale, pp. 43-50.

Jagtap, T.G. & A.G. Untawale, (1980). Effect of Petroleum products on mangrove seedlings. *Mahasagar Bull. Nat. Inst. Oceanog.* 13 (2): 165-173.

Jagtap, T.G., V.S. Chavan, and A.G. Untawale, (1993). Mangrove ecosystems of India: A need for protection. *Ambio* **22** (4): 252-254.

Jagtap, T.G., A.G. Untawale and S.N. Inamdar, (1994). Study of mangrove environment of Maharashtra coast using remote sensing data. *Indian J. Mar. Sciences*, **23**:90-93.

Jara, R.S., (1985). Traditional uses of the mangroves in the Philippines. *In: Mangrove Ecosystem of Asia and the Pacific: Status, Exploitation and Management* (eds.) C.D. Field and A.J. Dartnall, pp.104-113.

Jeyaseelan, M.J.P., V. Sundararaj, and M. Devaraj, (1991). Significance of mangroves in fisheries. *Proc. Of the Symposium on Significance of Mangroves, Pune.* India. (eds.) A.D. Agate, S.D. Bonde, K.P.N Kumaran, Maharashtra Assoc. Cultiv. Sci. Res. Inst. pp. 14-23.

Johnstone, I.M. & D.G. Frodin, (1982). Mangroves of the Papua sub region. In: *Monographiae Biologicae,* (ed.) J.L. Gressit. The Hague:Junk. **42**: 513-528.

Kapetsky, J.M., (1985). Mangroves, fisheries and aquaculture. FAO, Fish. Report 338 (suppl.): 17-36.

Kathiresan, K., (1995a). Quo vadis, mangroves? *Seshaiyana*, **3**: 25-28.

Kathiresan, K., (1995c). Studies on tea from mangrove leaves. *Environ. Ecol.*, **13** (2): 321-323.

Kathiresan, K., and A. Veera Ravi, (1990). Seasonal changes in tannin content of mangrove leaves. *The Indian Forester*, **116**(5): 390-392.

Kathiresan, K., and M. Pandian, (1991). Effect of UV on quality of black tea from *Ceriops decandra. Science and Culture*, **57**(3-4): 93-95.

Kathiresan, K., and M. Pandian, (1993). Effect of UV on black tea constituents of mangrove leaves. *Science and Culture*, **59**: 61-63.

Khanna, L.S., (1977). Principles and Practice of Silviculture, Khanna Bandhu, Dehra Dun, pp. 190-252.

Kongsangchai J., S. Panithsuko, S. Havanont, J. Laengthananatanakul, K. Supabhibool and S. Panitchart. (1982) *In: Proc. NRCT-JSPS, Rattanakosin Bicetennial Joint Semi Sci., & Mangrove Resources*, Phuket, Thailand, pp. 216-220.

Krishnamoorthy, R., A. Bhattacharya, and T. Natarajan, (1993). Mangroves and coral reef mapping of South Andaman Islands through Remote Sensing Sustainable Management of Coastal Ecosystems. (eds.) Swaminathan, M.S. and R. Ramesh, pp.143-151.

Krishnamurthy, K., (1985). The changing landscape of the Indian mangroves. *Proc. Symp. Biol. Util. Cons. Mangroves*: Nov. 1985, Kohlapur, India: 119-126.

Krishnamurthy, K., (1993). The Mangroves ENVIS News Letter, Annamalai University, **1**:1-3.

Krishnamurthy, K., A. Choudhury, and A.G. Untawale, (1987). Mangroves in India: Status Report, Govt of India, Ministry of Environment and Forests, New Delhi, pp. 150.

Kumar, Rajiv., (January, 1995). Mangrove Plantations in Goa, *The Indian Forester*, pp 3-6.

Kumar, Rajiv., (1998). Study on mangroves with special reference to its natural regeneration in Middle Andaman Forest Division. In: Indian Journal of Forestry, **21** (4): 357-362.

Lewis, R.R., (1982). Mangrove forests. In: *Creation and Restoration of Coastal Plant Communities,* (ed.) Lewis, R.R.. CRC Press, Boca Raton, FL, USA. pp. 153-172.

Ling, S.W., (1977). Aquaculture in Southeast Asian: *A Historical Overview.* Washington Sea Grant Publ. Seattle: Univ. Washington Press.

Lugo, A.E., (1980). Mangrove ecosystems: Successional or steady state? *Biotropica.* **12**:65-72.

Lugo, A.E., M. Sell, and S.C. Snedaker, (1973). *The Role of Mangrove Ecosystems: Properties of Mangrove Forest in South Florida,* Resource Management Systems Programme, Univ. of Florida (Gainesville), U.S.A. Report No. D1-DEEP, **74**:34-62.

Macnae, W., (1966). Mangroves in the eastern and southern Australia. *Aust. J. Bot*, **14**: 67-104.

Macnae,W., (1968). A general account of the fauna and flora of mangrove swamps and forests in the Indo-West Pacific Region. *In*: *Advances in Marine Biology,* Academic Press, London, **6**: 73-270.

Mall, L.P., S.K. Billore & D. Amritphale. (1982). Certain ecological observations on mangroves of the Andaman Islands. *Trop. Ecol.* **23**: 225-233.

Mall, L.P., V.P. Singh, A. Garge, S.M. Pathak, and S.M. Dandoria, (1985). Mangrove forest of Andamans and some aspects of ecology. *Proc. Nat. Symp., Biol. Util. Cons. Mangroves*: Nov. 1985, Kohlapur, India: 438-443.

Mall, L.P., V. P. Singh, and A. Garge, (1991). Study of biomass, litterfall, litter decomposition and soil respiration in monogeneric mangrove and mixed mangrove forests of Andaman Islands. *Tropical Ecology* **32**: 144-152.

Mathauda, G.S., (1957). The mangroves of India. *Proc. Mangrove Symposium.* Ministry of Food and Agri., Calcutta, pp. 67-86.

Matondkar, S.G.P., S. Mahtani & S. Mavinkurve, (1980a). The fungal flora of the mangrove swamps of Goa. *Mahasagar Bull. Nat. Inst. Oceanogr.* **13** (3): 5.

Matondkar, S.G.P., S. Mahtani & S. Mavinkurve, (1980b). Seasonal variations in microflora from mangrove swamps. *Indian J. Marine Sci.* **9** (2): 119-120.

Mercer, D.E. and L.S. Hamilton, (1984). Algunas ventajas economicas y naturales de los ecosistemas de manglares. La Naturaleza y sus Recursus **20** (2) : 14-19.

Milliman and Meade, (1983). In nature and resources. UNESCO, 32: No.2.

Moorthy, P., (1995). Effects of Ultraviolet B. radiation on mangrove environment. Physiological responses of *Rhizophora apiculata* Blume. *Ph.D. thesis, Annamalai University, India*, pp. 130.

Moorthy, P. & K. Kathiresan, (1995). Influence of nitrogen salts on growth and physiological responses of *Rhizophora apiculata* Blume in non-aerated water culture. *Pakistan Journal of marine Sciences,* 42.

Mulia, F., (1993). *Saran penyempurnaan pedoman sistem silvikultur hutan mangrove*. A recommendation for the Indonesian Government. (Unpublished).

Murty, C.S. & P.K. Das (1972). Premonsoon tidal flow characteristics of Mandovi estuary. *Ind. J. Mar. Sci.* **1**: 148-151.

Nam Vien Ngoc., (1994). Plantation to rehabilitate mangroves in Can Gio, Ho Chi Minh City. In: Proceeding of the national workshop *Reforestation and Afforestation of Mangroves in Vietnam* Can Gio, Ho Chin Minh City. 6-8 August, 1994. Hanoi. pp. 75-79.

Nam Vien Ngoc, Tran Viet My., (1992). Mangroves for production and protection. A changing resource system: A case study in Can Gio District, *South Vietnam. Field Doc. No 35*, Bangkok. Pp. 13-18.

Naskar, K.R., (1985). Population Pressure on the Mangrove Swamps on Sundarbans in India-Its Causes & Problems, Population Mapping. Monograph, NATMO Calcutta, **4**: 159-161.

Naskar, K.R. & D.N. Guha Bakshi, (1987). Mangrove Swamps of the Sundarbans- An ecological prospective, Naya Prakash, Calcutta – 700 006: 1-264.

Naskar, K.R. & A.K. Ghosh (1989). Status of the tidal and intertidal mangrove forests of the Sundarbans in India. *1st International Seminar on Coastal Environment in Asian region- Potentialities and Problems*; Dec. 8. Asian Marine Conservation Association, Cal. pp. 23-29.

Naskar, K.R. & R.N. Mandal, (1999). *Ecology and Biodiversity of Indian Mangroves*. Publisher-Milton book Company, Dehradun, (India), **1**: 3-348.

Navalkar, B.S., (1951). Succession of the Mangroves Vegetation of Bombay and Salsette Islands. *J. Bombay Nat. Hist Soc.* **50**: 157-160.

Nayak, S.T., (1993). Remote sensing applications in the management of Wetland ecosystem with special emphasis on management of mangrove ecosystem and coastal protection, Visakhapatnam, India, pp. 21.

Noakes, D.S.P., (1951). Notes on the silviculture of the mangrove forest of Matang, *Perak. Maly. Forester.*, **14**: 183-196.

Odum. W.E., and E.J. Heald, (1975). Mangrove forests and aquatic productivity. *In: Coupling of Land and Water Systems*, (ed.) P.D. Hasler. Springer -Verlang Berlin pp. 129-136.

Oertel, G., (1988). A geology do distritto de Goa *Common Serv. Geol.* Portugal 40 Libson.

Ong, J.E., (1978). The Malaysian mangrove environment. Paper presented at the *Regional Seminar on Human Use of the Mangrove Environment and Management Publications*, 4-8 December 1978, Dacca, Bangladesh.

Ong, J.E., (1982). Mangrove and aquaculture in Malaysia. *Ambio*, 11 (5): 252-257.

Padron, C. M., (1996). Mangrove ecosystem restoration in Cuba: a case study in Havana Province. *In*: *Restoration of Mangrove Ecosystems*, The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp.162-169.

Palaniselvam, V., (1995). Studies on the cyanobacterium *Phormidium tenue* (Menegh) Gormat for its utility in aquaculture, shrimp feed and as biofertilizer for mangroves. *M. Phil. dissertation, Annamalai University, India*, pp. 45.

Pannier, F. and R.F. Pannier, (1977). Interpretation fisioecologica de la distribution de manglares en las costas del continente Suramericano. *Intercencia*. **2** (3):153-162.

Parkinson, C.E., (1972). *A Forest Flora of the Andaman Islands*, M/S Bishen Singh Mahendra Pal Singh, Dehra Dun. pp. 163-168.

Parnetta, J.C., (Ed.): (1993). Marine protected area needs in the South Asian seas region, *A Marine Conservation and Development Report.* IUCN, Gland, Switzerland, pp. 77.

Parulekar, A.H., V.K. Dhargalkar & S.Y.S. Singbal, (1980). *Indian J. Marine Sci.* 9: 189-200.

Parulekar, A.H. & X.N. Verlencar, (1984). Status and prospects of fish farming in Goa. *Proc. Symp. Coastal Aquaculture.* **3**: 732-737.

Poon, Y.C., (1983). The management of acid sulphate soils. HMPB Experience Work shop on the management of acid sulphate soils of agriculture. Deptt. of Agril. and IADP West Johere, Kuala Lumpur.

Prain, D., (1903). Flora of Sunderbans. *Rec. Bot. Surv. India,* **2**: 231-370.

Premanathan, M., (1991). Studies on antiviral activity of marine plants. *Ph.D. Thesis Annamalai University, India,* 102 pp.

Puri, G.S. & S.K.Jain, (1957). The mangrove vegetation of Western India. *Proc. Mangrove Symposium*. Ministry of Food and Agri., Calcutta, pp. 51-57.

Purushan, K. S., (1991). Prospects of fish production from mangrove ecosystems. *Fish. Chimes.,* **11**(3): 24-26.

Qureshi, I. M., (1957). Botanical and Silvicultural features of mangrove forests of Bombay state. *Proceedings of the Mangrove Symposium.* (Ministry of Food and Agricultural) Govt. of India, Calcutta, pp. 20-26.

Qureshi, M.T., (1990). Experimental plantation for rehabilitation of mangrove forests in Pakistan. Mangrove Ecosystems Occasional Papers No. 4. UNESCO, New Delhi, pp.37.

Qureshi, M.T., (1996). Restoration of mangroves in Pakistan. The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp. 129-142.

Qureshi, M.T., (1999). Restoration of Mangroves in Pakistan, *In: Restoration of Mangroves Ecosystems.* The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp.129-142.

Rabinowitz D., (1975). *Proc. Int. Symp. Biol. & Mngt Mangroves* (eds) G. Walsh, S. Snedaker and H.J. Teas, Univ. Florida, Gainesville, Florida.**1**: 385-393.

Rabinowitz D., (1978). Early growth of mangrove seedlings in Panama and hypotheses concerning the relationship of dispersal and zonation. *Journal of Biogeography*, **5**: 113-133.

Rajagopalan, M.S., (1987). Mangroves as component of coastal ecosystems of the Andamans. *In: Proc. Symp. on Management of Coastal Ecosystems and Oceanic Resources of the Andamans* (eds.) Singh, N.T., Gangwar, B., Rao, G.C., Soundararajan, R., Andaman Sci. Assoc. Port Blair, pp. 1-7.

Ranganath, B.K., C.B.S. Dutt , and B. Manikiam, (1989). Digital mapping of mangroves in Middle Andamans of India. *Proc. 6th Symp. Coastal Zone '89, Charleston, South Carolina, American Society of Civil Engineers, New York.,* **1**: 741-750.

Rangel, J.F., (1980). Government of Goa, Forest Department. Working plan for North Goa Forest Division, 1979-80 to 1988-89. **1**:43-51.

Rao, V.S., (1957). Mangrove forests and the problems of reclaiming saline blanks. *Proc. Mangrove Symposium.* Ministry of Food and Agri., Calcutta, pp. 59-65.

Rao, A.N., (1987). Mangrove ecosystems of Asia and the Pacific. *In: Mangroves of Asia and the Pacific: Status and Management.* (eds. Umali, R.M., Zamora, P.M., Goter, R.R., Jara, R.S. and Camacho A.S.).Technical Report of UNDP-UNESCO Research and Training Pilot Programme on Mangrove Ecosystems in Asia and the Pacific (RAS/79/002). National mangrove committee and Philippines, Quezon city, Manila, Philippines, pp. 1-41.

Rao, T.A. and A.R.K. Sastry. (1972). An ecological approach towards classification of coastal vegetation in India. I. Strand Vegetation. *Indian Forester*. **98**: 594-607.

Rao, T.A. and A.R.K. Sastry, (1974). An ecological approach towards classification of coastal vegetation in India. II. Estuarine border vegetation, *Indian Forester*, **100**: 438-452.

Rao, T.A. and S. Chakraborti, (1987). Disributional resume of Coastal floristic elements in the Andaman and the Nicobar Islands, *Curr. Sci.*, **56**(20): 1045-1051.

Ravikumar, S., (1995). Nitrogen fixing Azotobacters from the mangrove habitat and their utility as biofertilizers. *Ph.D. thesis Annamalai University, India*. pp. 202.

Razani, Ujang, (1982). The role of mangrove forests in the management of coastal zone. *Proc. Workshop Ecol. Basis* Rational Resource Utilization Humid Trop. S.E. Asia, Univ. Pertanian Malaysia.

Roxburgh, W.A., (1814). *Hortus Bengalensis* or a Catalogue of plants growing in the Honourable East India Company Botanical Garden at Calcutta, Serampore Mission Press, India, pp. 105.

Rutzler, K., (1969). The mangrove community, aspects of its structure, faunistics and ecology. *In: Lagunas costeras Un Symposia.* UNAM-UNESCO, pp: 515-536.

Saenger, P., (1986). Bangladesh Mangrove Afforestation Project. Report prepared for Govt. of Bangladesh, Sheeden Pacific Pty. Limited,Melbourne, Australia, pp. 63.

Saenger, P., (1996). Mangrove restoration in Australia: A case study of Brisbane International Airport. The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp. 39-48.

Saenager, P., E.J. Hegerl, and J.D.S. Davie, (1983). Global Status of mangrove ecosystems, Commission on ecology papers No. 3, IUCN, Gland, Switzerland, pp. 88.

Sahani, K.C., (1957). Mangrove Forests in Andaman and Nicobar- Islands. *In: Proc. Mangrove Symposium*, Calcutta, Oct. 16-19, 1957. pp. 114-123.

Schimper, A.F.W., (1891). *Die-Indo. Malayische* Strand Flora. *Bot. Mitteil Trop. Jena* **3**:1-204.

Seidensticker, J. and Md. Abdul Hai., (1983). *The Sunderbans Wildlife Management Plan*: Conservation in the Bangladesh coastal zone. WWF/ IUCN, Gland, Switzerland, pp.120.

Semeniuk, V., K.F. Kenneally, and P.G. Wilson, (1978). *Mangroves of Western-Australia*, Western Australian Naturalists Club, Perth Handbook. No. 12 pp. 92.

Semeniuk, V., (1983). Mangrove distribution in north-western Australia in relationship to regional and local fresh water seepage. *Vegetation*, **53**: 11-31.

Seth, S.K. & G.S. Mathauda, (1957). Silvicultural practices with respect to the mangrove forests outside India. *Proc. Mangrove Symposium*. Ministry of Food and Agri., Calcutta, pp. 89-95.

Shinde, S.D. and F.R. Mustafa, (1974). Geographical analysis of the flora distribution and composition in the Terekhol inlet. *Geogr. Res. India,* **36**(1):23-30.

Siddiqi, N.A. and M.R. Islam, (1988). Studies on fruit size, seed production and viability of seeds keora (*Sonneratia apetala*). *Bano Biggyan Patrika*. **18**: 57-62.

Siddiqi, N.A., M.A.S. Khan, M.R. Islam & A.K.F. Hoque, (1992). Underplanting a means to ensure sustainable mangrove plantations in Bangladesh. *Bangladesh Journal of Forest Science.* **21**: 1-6.

Siddiqi, N.A., M. R. Islam, M.A.S. Khan and M. Shaidullah, (1993). Mangrove nurseries in Bangladesh. ISME Mangrove Occasional Papers no.1. ISME, Japan, pp. 171.

Siddiqi, N.A., M.A.S. Khan, (1990). Growth performance of mangrove trees along the coastal belt of Bangladesh. Mangrove Ecosystem Occasional Papers. UNDP/UNESCO. No. **8**: 5-11.

Siddiqi, N.A., M.A.S. Khan, (1996). Planting techniques for mangroves on new accretions in the coastal areas of Bangladesh. The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp. 145-154.

Sidhu, S.S., (1963). Studies on Mangroves. *Proc. Indian Acad. Sci.* **33** (8): 129-136.

Singh, V.P., L.P. Mall, A. Garge and S.M. Pathak, (1986). Mangrove forests of Andaman Islands in relation to human interference. *Environmental Conservation* **13**: 169-172.

Singh, N.T., and A.D. Mongia, (1987). Problems and prospects of different components of ecosystems in the Andaman and Nicobar Islands. *J. Indian Soc. Coastal Agri. Res.* **5**(1): 77-84.

Singh, N.T., A.D. Mongia and A.N. Ganeshamurthy, (1988). Soils of Andaman and Nicobar Islands, CARI, Port Blair Bulletin. No.1 pp. 78.

Sinha, B.P., (1994). Conservation and Management of Mangroves in Andaman and Nicobar Islands, M.S. Swaminathan Research Foundation, Chennai, pp. 423-426.

Snedaker, S.C., (1987). Mangrove forests of South America: Some traditional uses. *Bakawan*, **1**:10-12.

Soemodihardjo, S. and I. Sumardjani, (1994). Re-afforestation of mangrove forest in Indonesia. In: Proceedings of the workshop on ITTO project: *Development and Dissemination of reafforestation Techniques of Mangrove Forests.* 18-20 April 1994. Bangkok, Thailand, 99-116.

Soemodihardjo, J., P. Wiroatmodjo, F. Mulia and M.K. Harahap, (1996). Restoration of mangroves in Indonesia: a case study of Tembilahan, Sumatra. The International Society for Mangrove Ecosystems, Produced for ISME by John Witzig & Company Pty Ltd. Mullumbimby, NSW 2482. Australia, pp. 97-109.

Srinivasan, M.S., (1978). New chronostratigraphic division of the Andaman-Nicobar Late Ecnozoic. *Recent Research in Geology.* **4**:22-36.

Steinke, T.D., (1975). Some factors affecting dispersal and establishment of propagules of *Avicennia marina* (Forsk.) Vierh. *In*: *Proc. Int. Symp. Biol. & Mngt Mangroves*, (eds) G. E. Walsh, S. C. Snedaker and H.J. Teas, Inst. of Food & Agri. Sci., Univ. of Florida, Gainesville, Florida. **I**: 385-393, **II**: 402-14.

Steinke, T.D. and L.M. Charles, (1984). Productivity and phenology of *Avicennia marina* (Forsk) Vierh. and *Bruguiera gymnorrhiza* (L.) Lam. In Megni estuary, South Africa, In: *Physiology and management of mangroves* (eds. H.J. Teas), pp. 25-34.

Subramonia Thangam, T., (1990). Studies on marine plants for mosquito control. *Ph. D. Thesis, Annamalai University, India*, pp.68.

Sumardjani, L. and F. Mulia, (1994). Some experience on the rehabilitation of mangrove forest (industrial forest plantation) in Palembang. *In*: *Proceedings of the Regional Seminar on Ecosystem Rehabilitation of Ecotone II.* 29-31 March 1993, Jakarta, Indonesia: 65-68.

Sugden, E.A.N., and H.G von Cube, (1978). Industrial uses of mangrove (*Rhizophora racemosa)*. In: Proc. of 8th World Forestry Congress, Jakarta. FID/0-9, pp. 9.

Tang, H.T., A.H. Haron, and E.K. Cheah., (1984). Mangrove forests of Peninsular Malaysia- A review of management and research objectives and priorities. *In*: *Proceedings of the Asian Symposium on Mangrove Environment: Research and Management,* (eds.) E. Soepadmo, A.N. Rao and D.J. Macintosh, 25-29 August 1980, Kuala Lumpur.

Teas, H.J., (1979). Silviculture with saline water. *In*: *The Biosaline Concept* (ed. A. Hollaender). Plenum Publ. Corp., New York. pp. 117-161.

Thangam, T.S., and K. Kathiresan, (1992a). Mosquito larvicidal activity of mangrove plant extracts against *Aedes aegypti. International Pest Control*, 34(4): 116-119.

Thangam, T.S., and K. Kathiresan, (1993). Repellency of marine plant extracts against *Aedes aegypti*. *Int. J. of Pharmacognosy,* **31**: 33-46.

Thangam, T.S., and K. Kathiresan, (1994). Mosquito larvicidal activity of *Rhizophora apiculata. Int. J. of Pharmacognosy*, **32**: 33-36.

Tikader, B.K., and A.K. Das, (1985). *Glimpses of Animal Life of Andaman and Nicobar Islands. Spl. Publ. Zool. Surv.* India, Calcutta: I-XII pp.1-70.

Tomlinson, P.B., (1971). The shoot apex and its dichotomous branching in the *Nypa* palm. *Ann. Bot. Lond.* **35**: 865-879.

Troll, W. and D. Drangendroff, (1931). Uber die Luftwurzeln von *Sonneratia* und ihre biologische Bedenlurig. *Planta* **13**:311-473.

Troup, R.S., (1921). *The Silviculture of India Trees*. Oxford at the Clarendon Press. pp 1995.

Tuck, Chang Hung (1987). Country Report: Malaysia. *In*: *Mangroves of Asia and the Pacific: Status and Management*, (eds.) R.M. Umali, *et al.*, Technical Report of the UNDP/UNESCO Research and Training Pilot Programme on Mangrove Ecosystem in Asia and the Pacific (RAS/79/002). pp. 131-150.

Umali, R.M., (1985). Utilization and allocation of mangrove resources. *In: Report on the Workshop on the Conservation of Mangrove Areas to Paddy Cultivation.* Organised by UNDP/UNESCO (RAS/79/002) in Philippines pp. 30-47.

Untawale, A.G., (1978). Mangrove Research in India. *Regional Seminar on Human Uses of the Mangrove Environment and Management Implication.* Bangla Desh, pp. 1-20.

Untawale, A.G., (1980). Present status of the mangroves along the West Coast of India. *Asian Symp. Mangr. Environ. Res. Mgmt.,* Kuala lampur (Malaya): pp. 1-26.

Untawale, A.G., (1984). Present status of mangroves along the West Coast of India, *Proc. Asian Sympo. Mangrove Environment- Res & Mangagement,* (ed. Soepadmo). pp. 57-74.

Untawale, A.G., (1985). Mangrove in India: Present status and multiple use practices, UNDP/UNESCO Regional Mangrove Project, pp. 67.

Untawale, A.G., (1987). Conservation of Indian mangroves- A national prospective. *In*: *Proc. Contribution in Marine Sciences*, Dr. S.Z. Qasim 60th Birthday Volume (eds. Desai, Swamy and Das). NIO, Goa, pp. 85-101.

Untawale, A.G., (1987). Some aspects of mangrove afforestation along the Central West Coast of India, In: *Afforestation of Salt Affected soils* (eds. R.S. Rana) CSSIR, Karnal (India) **2**:133-150.

Untawale, A.G., (1987). Country Reports: Asia, India. *In. Mangroves of Asia and the Pacific: Status and Management.* Technical Report of UNDP/UNESCO Research and Training Pilot Programme and Mangrove Ecosystems in Asia and the Pacific, pp. 51-87.

Untawale, A.G., (1992). Rehabilitation of coastal wetlands of India. In: Ecosystem Rehabilitation, Ecosystem Analysis and Synthesis (Edited by.). Mohan K. Wali. Academic Publishing, The Hague, The Netherlands. **2**: 333-348.

Untawale, A.G., (1993). Development of an intertidal mangrove nursery and afforestation techniques along the Indian Coast. *In*: *Towards the Rational Use of High Salinity Tolerant Plants.* (eds. H. Lieth and A.Al. Masoom) Kluwer Academic Publishers, Netherlands, **1**:371-378.

Untawale, A.G., (1996). *Restoration of Mangroves along the Central West Coast of Asia.* In: Restoration of Mangrove Ecosystems, ISME, Japan, pp. 11-124.

Untawale, A.G., S.N.Dwivedi and S.Y.S. Singbal. (1973). Ecology of Mangrove in Mandovi and Zuari estuaries and the inter-connecting Cumbarjua Canal of Goa. *Indian J. Mar. Sci.* **2**:47-53.

Untawale, A.G. & A.H. Parulekar, (1976). Some observation on the ecology of an estuarine mangrove of Goa. *Mahasagar. Bull. Nat. Inst. Oceanography,* **9** (1&2): 57-62.

Untawale, A.G., N.B. Bhosle, V.K. Dhargalkar, S.G.P. Matondkar & S. Bukhari, (1977). Biochemical changes in Mangrove foliage during growth and decomposition. *Ind. J. Mar. Sci.* **6**: 104-106.

Untawale,A.G., S. Wafar and T.G. Jagtap, (1980). Application of remote sensing technique to study the distribution of mangrove along the estuaries of Goa. *Proc. 1st Intern. Wetland Conf.* India.

Untawale,A.G., S. Wafar and T.G. Jagtap, (1982). Application of remote sensing technique to study the distribution of mangroves along the estuaries of Goa. *In: Wetlands: Ecol & Management*. Proc. Ist. *Inter. Wetlands Conference,* New Delhi, pp. 51-67.

Untawale, A.G., S. Wafar, (1985). Coastal Karnataka and its ecodevelopment , In: *Karnataka State of Environment Report*. !984-85. pp. 1-11.

Untawale, A.G., S. Wafar and T.G. Jagtap, (1992). Status of mangroves along the countries bordering the Arabian Sea. *Oceanography of the Indian Ocean* (ed.) Desai, B.N., Oxford and IBH, New Delhi, India, 239-245.

Vannucci, M. (1989). *The Mangroves and Us. A Synthesis of Insights.* Indian Association of the Advancement of Science, New Delhi.

Vannucci, M., (1997). Supporting Appropriate Mangrove Management. Intercoast Network. Special edition, **1**:1, 3, 42.

Vasudeva Rao, M.K., (1986). A preliminary report on the Angiosperms of Andaman-Nicobar Islands. *J. Econ. Tax. Bot.* **8** (1): 107-184.

Wacharakitti, S., (1983). Mangrove Ecosystem in General pp. 22-23. ESCAP/ UNESCO/ NRCT Regional Remote Sensing Training Course of Mangrove Ecosystem Bangkok, Nov. 28-Dec. 16.

Wafar, S., (1987). Ecology of Mangrove along the estuaries of Goa. *Ph.D. Thesis, Karnataka University, Dharwad.* pp-18, 175-179.

Wagale, B.G. (1982). Geomorphology of the Goa Coast. *Proc. Indian Acad. Sci.* (Earth, Planet Sci.). **91**: 105-117.

Waheedkhan, M.A., (1957). Ecological studies on the mangrove forests in India. *Proc. Mangrove Symposium,* Ministry of food and Agri., Calcutta, pp. 97-109.

Walsh, G.E., (1967). An ecological study of Hawaiian mangrove swamp. *In: Estuaries,* G.H. Lauff (eds.). Am. Assoc. Adv. Sci., D.C. Washington, pp. 420-431.

Walter, H., (1977). Climate. *In Ecosystem of the World: Wet Coastal Ecosystems:* (ed.). V.J. Chapman. Elsevier, New York, **1**:54-66.

Walter, H. & M. Steiner, (1936). Oekologie der ost-afrikanschen Mangroven: *Z. Bot.* **30**: 65-93.

Wechakit, D., (1997). Growth and survival of private mangrove plantations (*Rhizophora apiculata*) at Amphoe Amphawa, Samut Songkram Province. *M.S. Thesis, Kasetsart University,* Bangkok. Thiland.

Wirjodarmodjo, H. & Z. Hamzah, (1984). Beberapa pengalaman perum Perhutani dalam pengelolaan hutan mangrove. *In*: *Biology and Ecology of Mangroves*, (eds.) S. Soemodihardjo *et al.*, The Hague: Dr. W. Junk Publ. pp. 29-40.

Wium-andersen, S. and B. Christensen, (1978). Seasonal growth of mangrove trees in southern Thailand II. Phenology of *Bruguiera cylindrica, Ceriops tagal, Lumnitzera littorea* and *Avicennia marina. Aquat. Bot.,* **5**: 383-390.

Zahari, A.B., (1983). Interim report of the Pilot Project on the effects of field drainage on potential acid sulphate soils in West Johore. *Workshop on the Management of Acid Sulphate Soils of Agriculture*. Dept. of Agric. and IADP West Johore, Kuala Lumpur.

APPENDIX

RELATED PUBLICATIONS

APPENDIX

RELATED PUBLICATIONS

Information gathered from time to time by field study of mangroves in Goa and Middle Andaman were analyzed and documented in the form of research papers. So far, six numbers of following papers have either been published or approved for publication and some more papers are under consideration for publication:

(1) Mangrove plantations in Goa.

Published in the Journal, "The Indian Forester, January 1995". Copy of the paper is enclosed herewith.

(2) Mangroves in Middle Andaman Forest Division with special reference to their natural regeneration.

Published in the Journal, "Indian Journal of Forestry, December 1998". Copy of the paper is enclosed herewith.

(3) Artificial regeneration of mangroves.

Published in the Journal, "Indian Journal of Forestry, August 1999 ". Copy of the paper is enclosed herewith.

(4) A study on estimation of area under mangroves and its growing stock in Middle Andaman Forest Division.

Approved for publication in the Journal, "Indian Journal of Forestry, March issue of Vol.23 (1) – 2000" vide letter No.IJF/99 dated 07.7.1999.

(5) Study on the determination of depth of sowing, average length and weight and viability period in Ceriops tagal in Middle Andaman.

Approved for publication in the Journal, "Indian Journal of Forestry, March issue of Vol.23 (1) – 2000 vide letter No.IJF/99 dated 07.7.1999.

(6) Distribution of mangroves in Goa

Approved for publication in the Journal, "Indian Journal of Forestry".

MANGROVE PLANTATIONS IN GOA

RAJIV KUMAR*

Introduction

Forests of Goa spread over an area of 1250 km^2 play a very important role in adorning the natural landscape. The total natural estuarine mangrove area in Goa has been estimated around 2000 ha, out of this mangrove area about 900 ha, is along the Zuari estuary, about 700 ha along the Mandovi estuary, about 200 ha along the Cumbarjua canal and the remaining along Terekhol, Chapora, Sal, Talpona and Galgibag estuaries. Mangrove forests check the soil erosion along the estuaries and are excellent habitat for Wildlife especially birds and fishes. Leaves of mangrove species, *Avicennia marina* are used as fodder for mulching animal while another genus of mangrove *Sonneratia* is used for honey production by bees. Due to high calorific value mangrove wood is used as firewood, It is also used for making charcoal. Mangrove timber is termite resistant and its bark is a rich source of tannin. Due to various uses of mangrove trees, mangrove forests in Goa were exploited to a considerable extent and the deforestation drew our attention to the urgent need of conservation of mangrove ecosystem. It was also decided to restore those mangrove areas by way of afforestation which have been degraded much mainly due to biotic interference. Reclamation of mangrove areas for paddy cultivation, for human habitation and for setting up of Industries, Pisciculture etc. are also some of the main factors responsible for the destruction of mangrove forests in Goa in the past. Realising the immense importance of mangrove species, the Government of Goa has declared fifteen mangrove species as 'Protected Species' and their felling has been banned for a period of 10 years. 178 ha of best mangrove area at Chorao (Goa) has also been declared as Reserved forests.

Mangrove Afforestation Programme

The Forest Department of Goa started Mangrove plantation works in the year 1985. Since then we have taken up 481.50 ha of plantation upto March 1993. These plantations have been taken up along the Zuari and Mandovi estuaries and along the Cumbarjua canal (Table 1). During 1991-92, a Mangrove Management Plan for Goa was prepared which was approved by the State Level Steering Committee and subsequently by the Govt. of India. As per the plan we have to take up 100 ha of mangrove plantations each year from 1991-92 onwards for a period of five years. The action plan has been undertaken with the financial assistance provided by the Government of India.

Nursery Technique

A mangrove nursery should preferably be located near the estuary or sea in the low lying area which gets inundated during the

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Table 1

Yearwise Mangrove plantations in Goa

Year of planting	Locality	Total area(ha)	Species used in planting.
1985-86	Chorao Island	75.00	*Rhizophora mucronata, Rhizophora apiculata* and *Avicennia officinalis.*
1986-87	Chorao Island	20.50	-do-
1987-88	Chorao Island	56.00	-do-
1988-89	Diwar Island, Piedade, Cumbarjua, Madel, Mude	48.75	-do-
1989-90	Varando, Ekoshi	54.75	-do-
1990-91	Ekoshi, Patto, Rua de Ouram.	26.50	-do-
1991-92	(a) 26 ha at Madkai along Zuari estuary. (b) 24 ha along Mapusa river	50.00	*Rhizophora mucronata, Rhizophora apiculata, Avicennia marina, Bruguiera gymnorhiza, Kandelia rheedi.*
1992-93	(a) 30 ha along Zuari estuary between Borim and Shiroda (b) 55 ha along Cumbarjua canal. (c) 85 ha along Mapusa river.	150.00	-do-
1993-94	(a) 35.00 ha along Mandovi Estuary/ Mapusa river. (b) 65.00 ha along Zuari estuary.	100.00*	-do-
	Total	581.50 ha	

* Target for 1993-94 Work in progress.

high tide. This type of location ensures automatic watering of the mangrove seedlings twice a day during the high tide, thereby reducing the cost of raising seedlings in the nursery. As far as possible, nursery site should also by close to planting site so as to minimise the cost of transportation of seedlings from the nursery to the planting site.

Some of the mangrove species like *Rhizophora, Bruguiera* and *Kandelia* are viviparous. Matured and healthy propagules from these species are collected and directly planted in the field. Therefore, seedlings of these species are not being raised in the nursery. On the other hand aviparous species of mangroves like *Avicennia*, *Sonneratia* etc are raised in the nursery for eventually planting out.

To raise the seedlings of aviparous mangrove species in the nursery, preperforated polythene bags of 12 cm x 20 cm size are filled with sandy/silty clay and are arranged in the beds. To provide support to these filled polythene bags, a framework made up of bamboo splinters is used along the boundary of the individual bed. Perforated polythene bags are used in the nursery so as to promote interaction of water inside and outside the polythene bag. All the nursery works are done during low tide.

The fruit of aviparous species contains a well developed seed inside. The seed germinates within the fruit. Fruits of those aviparous species mature during monsoon period (July-September). Mature fruits drop in the water and by the wave action they get deposited on the banks of rivers/estuaries. These seeds are collected and healthy seeds are sown in the already filled polythene bags in the nursery. Fruit should be placed about 12 mm deep in the soil. After a period of about 12 to 15 days seedling comes out. These seedlings attain a height of 40 to 45 cm in one year and may be used for planting in the field.

Plantation Technique

In the areas of relatively higher salinity *Rhizophora mucronata*, *Avicennia marina*, *Bruguiera parviflora* and *Sonneratia alba* have shown good growth results while in the areas of relatively lower salinity *Rhizophora apiculata*, *Avicennia officinalis*, *Kandelia rheedi* and *Sonneratia alba* have shown good growth results. Natural mangrove species present in the vicinity of the planting site also guide us regarding suitability of the particular mangrove species on a particular site.

In most of the places, area available for planting on both the banks of the estuaries is marked by two conspicuous zones with their boundary running along the estuary. First zone is that which is away from the centre of the river and characterised by the presence of pneumatophores, grasses etc. and the second zone is closer to the centre of the river/estuary and devoid of any vegetation. It is only deposition of the sandy/silty clay on the banks. In the past, planting of mangrove species have been tried in both these zones and it has been observed that survival percentage in the first zone is 80% or more while in the second zone survival percentage varies from 5-10%. In the first zone pneumatophores and/ or grasses bind the soil particles together and also reduce the resultant impact of wave action on individual young propagules/ seedling, thereby, help the young seedlings in their establishment. In the second zone soil is loose and wave action is much stronger as compared to first zone, therefore, young seedlings of mangrove do not get proper anchorage for their establishment. Based on our past experiences it has now been decided to take up planting work in the first zone only. Planting technique divided into two groups (a) Planting of viviparous mangrove species, and (b) Planting of aviparous mangrove species, based on their mode of regeneration.

(a) *Planting of Viviparous Mangrove Species* : Viviparous mangrove species like

Rhizophora, Ceriops, Bruguiera and *Kandelia* give rise to propagules on the mother plant itself. Matured and healthy propagules of these species are collected without damaging the radicle during April-July for planting out directly. Mature propagule is one which shows development of a band of pale tissue near the fruit wall. Propagules planted within seven days from the date of collection. The propagule is planted at 4 cm to 8 cm deep in the soil depending upon the size of the propagule, New leaves start appearing in the propagules after 15 days of planting.

(b) *Planting of Aviparous Mangrove Species* : Seedlings of Aviparous genus like *Avicennia* and *Sonneratia* are raised and maintained in the nursery for about a year. By this time average height of seedlings reaches to 40 cm to 45 cm. These seedlings are being used for plantation when the propagules of viviparous mangrove species are not available. These seedlings are transported from the nursery site to the planting site in boats.

Assessment of success of Mangrove plantations

On the basis of overall results, plantations of mangrove species in Goa can be graded as very successful. In the beginning years the survival percentage in the plantation was low (around 50% or less) mainly due to extensive fishing activities which are very common along the rivers and estuaries. Use of drag fishing net has caused maximum damage to the young seedlings. While pulling the net out, young seedlings of mangroves also get entangled in the net and are uprooted. It is felt that fishing should not be allowed on the site of plantation for a period of five years from the year of planting. So far, no rule has been framed in this regard and we are following the policy of pursuasion to check this problem. Another reason for the low survival percentage is interference by cattle. They damage the plants on entering on the plantation site. Still another reason for the low survival percentage was the planting of seedlings/propagules in the pnuematophere free zones along the estuaries as discussed earlier. To minimise the damage to the mangrove plants and to ensure maximum survival percentage we have intensified patrolling with our existing staff and sought and encouraged people's participation in the mangrove plantation and nursery works. We have not decided in favour of fencing and watch and ward at most of the planting sites as it is a very costly affair. Mangrove plantation is a labour intensive work and those rural people residing close to the nursery/plantation sites are preferred for these works. While their engagements with us they are motivated to protect these plants even after the completion of the plantation work. As their residences are close to the planting sites, they can guard the plantations very effectively. On personally meeting and talking to few labourers it was felt that they have developed some sort of affinity with these plants which were raised by them. The affinity definitely inspires them to protect these plants. Good results of our efforts have come out and in the recent plantations survival percentage is remarkably high. To further minimise the problem of seedling damage while fishing in and around the planting site, we are seeking co-operation of the State Government through Captain of Ports, Block Development Officer etc.

Cost analysis of Mangrove plantations

Majority of the plantation work has been undertaken by using direct planting method which involves planting of viviparous mangrove species. This method is much cheaper than the planting of aviparous species which involves raising of the nursery and then planting out one year old seedlings. Cost of Nursery and plantation work in Goa has been increased by 40% following 40% increase in daily wages of labourers w.e.f. 1.4.91 and general increase in the cost of polythene bags and other miscellaneous items.

(a) *Cost of raising mangrove seedlings in the Nursery* : Maximum average cost of one mangrove seedling raised comes to be Rs. 0.70. Approximate break-up of this expenditure is shown below :

Particulars	Max. Av. cost (Rs.)
(1) Site and bed preparation, filling of polythene bag and arranging in the bed.	0.40
(ii) Cost of seed collection, its sowing in the polythene bag, maintenance works and miscellaneous charges.	0.10
(iii) Cost of polythene bag of 12 cm x 20 cm size (200 gauge)	0.20
Total	0.70

(b) *Cost of raising mangrove plantation by using direct planting method* : To raise one hectare of plantation, maximum average cost comes out to be Rs. 1700.00. Approximate break-up of this expenditure is as follows :

Particulars	Max. Av. cost (Rs.)
(i) Survey and demarcation of the area.	100.00
(ii) Collection of propagules and transportation charges.	600.00
(iii) Planting work and other miscellaneous charges.	1000.00
Total	1700.00

(c) *Cost of casualty replacement in mangrove plantation by using direct planting method* : On an average, the maximum average cost of casuality replacement in one hectare of mangrove plantation comes out to be Rs. 700.00. Approximate break-up of this expenditure is as follows :

Particulars	Max. Av. cost (Rs.) per ha
(i) Cost of collection of propagules and transportation charges,	260.00
(ii) Planting work and other miscellaneous charges	440.00
Total	700.00

Conclusion

Efforts which have been done so far in the field of plantation in order to restore the maingrove ecosystem in Goa have yielded good results but lot of work in this field is yet to be done. Apart from taking plantation works under "Mangrove Management Plan for Goa" along the estuaries of Mandovi, Zuari and Cumbarjua canal, it is envisaged to take up plantation work in the degraded mangrove areas along five other estuaries namely Terekhol, Chapora, Sal, Talpona and Galgibag. The immediate challenge before us in this field is to protect our plantations from biotic interference and upgrade our techniques to minimise the cost of plantation and to ensure maximum survival percentage. We are also contemplating to introduce those mangrove species which are not naturally found in Goa. Our mangrove plantations are a thing of pride, beauty and ecstasy for us.

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SUMMARY

Due to the degradation of mangrove forests in Goa in the past mainly do to biotic interference, the Forest Department of Goa has started planting mangrove species in the degraded areas to restore these forests to their pristine glory. The plantations raised so far can be graded as very Successful on the basis of overall results and are playing crucial role in the improvement of mangrove ecosystem in Goa. Our endeavour is to have a sound mangrove ecosystem primarily by adopting afforestation and conservation activities.

गोवा के वायुशिफ वन

राजीव कुमार

सारांश

विगत काल में गोवा में वायुशिफ वनों का मुख्यतः जैविक हस्तक्षेप के कारण व्याहास होने से गोवा के वन विभाग ने इन व्याहरित क्षेत्रों को उनकी पुरानी शोभा पर पहुंचाने के लिये इनमें वायुशिफ जातियों के वृक्ष लगाना आरंभ किया है। अब तक लगाए गए रोपवनों को उनके समग्र परिणाम देखते हुए बहुत "सफल" की श्रेणी में रखा जा सकता है और गोवा वायुशिफ परिस्थिति संहति को सुधारने में ये वन बहुत महत्वपूर्ण भूमिका निभा रहे हैं। हमारा प्रयास है कि प्रधानतः वनीकरण और संरक्षण क्रियायें अपनाकर ही एक स्वस्थ वायुशिफ परिस्थिति संहति तैयार कर ली जाए।

References

Anon. (1991). Mangrove Management Plan for Goa. *Report of Research and Utilisation Division*, Forest Dept., Goa. pp. 12-21 (unpublished).

Anon. (1987). Mangrove of India - Status report. *Report of Govt. of India,* Ministry of Environment and Forests, New Delhi. pp. 52-55.

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STUDY ON MANGROVES WITH SPECIAL REFERENCE TO ITS NATURAL REGENERATION IN MIDDLE ANDAMAN FOREST DIVISION

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Abstract

For effective conservation and intensive management of mangrove resources, detailed basic information about their occurrence and state of natural regeneration is required (in addition to various other information). The present study deals with these two aspects and observations, results and recommendations based on this study have been described in detail in the paper.

Introduction

Andaman and Nicobar group of Islands (India) is located in the Bay of Bengal between 6^0 to 14^0 North latitude and 90^0 to 94^0 East longitude. The islands are over 500 in number and are the exposed parts of a sub-merged mountainous hill range starting from Arakanyoma (Myanmar) in north and Sumatra in south. Total geographical area of the islands is 8249 sq. km and its 86% , i. e., 7094 sq. km is under forest cover. As per official records 777.69 sq. km area is covered with Mangroves. The coastline is about 1962 km. Mean maximum temperature and mean minimum temperature on the island are 30^0 C and 23^0 C, respectively. Relative humidity varies from 70% to 90%. Mean annual rainfall is 300 cm. Population of A & N islands is 2,80,661 and density of population is 34 per sq. km.

Middle Andaman Forest Division is situated between the latitudes 12^0 15' and 12^0 50' North and longitude 92^0 40' and 93^0 50' East. Its total geographical area is 998.44 sq. km, out of which 233.95 sq. km is covered with mangroves as per official records, which amounts to 23.4% of total geographical area of the division. Mangrove swamps are mainly located along various creeks and sheltered areas, where mangroves get protection against the wave action for their establishment. Most of the mangroves occur toward eastern side of Middle Andaman Main Island and come under territorial jurisdiction of Bajalungta, Bakultala, Rangat, Betapur and Long Island forest ranges. Although Dagar, Mongia and Bandopadhyaya have reported about 30 mangrove species from Middle Andaman in their book titled "Mangroves of Andaman and Nicobar Islands". This study is confined to 19 important species of Mangroves which are relatively common in Middle Andaman. This work aims at studying occurrence of mangroves and to have a fair idea about the state of natural regeneration of mangroves in different parts of Middle Andaman Forest Division. Observations and inferences derived from the study will be useful in better conservation and management of the unique mangrove ecosystem.

Methodology

Mangrove areas of each of above mentioned ranges were visited several times and on the basis of observations, a list of mangrove species in decreasing order of abundance was prepared (Table-1). Zonation pattern in mangroves was also noticed which is given in Table-2. Range-wise occurrence of mangroves was also noted which is shown in Table-3.

Natural regeneration in mangrove forest occurs in the form of plants of varying heights, which increase with age. A mangrove plant above 90 cm height can be considered as well established regenerating plant.

Table-1: Mangroves of Middle Andaman Forest Division in descending order of abundance

S.No	Name of the Species	Habit	General habitat	Occurrence	Salinity Zone	Remarks
(A)	(B)	(C)	(D)	(E)	(F)	(G)
1	*Rhizophora apiculata*	Tree	Towards water front	+++	High	Most abundant species. All along the creeks towards water front side, pure patches can be seen. Also seen occurring towards landward side along with other mangrove species.
2.	*Rhizophora mucronata*	Tree	Towards water front	+++	High	Less abundant compared to *Rhizophora apiculata* but pure patches can be seen along the creeks towards waterfront side. Rarely found on landward side.
3.	*Bruguiera gymnorhiza*	Tree	Landward side	+++	High to Medium	Third most abundantly occurring mangroves in Middle Andaman. Tall trees up to 25-30 m height are common.
4	*Ceriops tagal*	Small Tree	Landward side	+++	Medium to Low	--
5.	*Phoenix paludosa*	Palm	Landward	+++	Low	Common in muddy areas.
6.	*Avicennia officinalis*	Tree	Mainly Landward side	++	High to Low	*Avicennia* is found in the form of scattered trees but at few places like Uttara, Nimbutala, Lalaji Bay, huge areas are under almost pure *Avicennia*.
7.	*Avicennia marina*	Tree	Mainly Landward side	++	High to Low	-
8.	*Excoecaria agallocha*	Tree	Landward side	++	Low	-
9.	*Acrostichum aureum*	Fern	Landward side	++	Low	At few places big patches are fully infested with fern.
10	*Lumnitzera littorea*	Tree	Landward side	++	Low	-
11	*Xylocarpus granatum*	Tree	Landward side and Seaward side	++	Low	-
12	*Xylocarpus moluccensis*	Tree	Landward side and Seaward side	++	High to Medium	-
13	*Nypa fruticans*	Palm	Landward side	++	Low	Common in muddy areas.
14.	*Heritiera littoralis*	Tree	Landward side	++	Low	-

Contd..

(A)	(B)	(C)	(D)	(E)	(F)	(G)
15.	*Aegiceras corniculatum*	Shrub	Landward side	+	Low	-
16.	*Sonneratia alba*	Tree	Towards Waterfront side	+	High to Medium	- -
17.	*Sonneratia caseolaris*	Tree	Towards Waterfront side	+	Low	-
18.	*Acanthus ilicifolius*	Shrub	Landward side	+	High to Medium	-
19.	*Lumnitzera racemosa*	Tree	Landward side	+	Low	-

+ = Rare, ++ = Common and +++ = Abundant

Table -2 : Zonation in Mangroves of Middle Andaman

S.No	Name of the Species	Presence in different Zones		
		Water Front Zone	Middle Zone	Landward Zone
1.	*Rhizophora apiculata*	✓	✓	
2.	*Rhizophora mucronata*	✓	✓	
3.	*Sonneratia alba*	✓		
4.	*Xylocarpus granatum*	✓		✓
5.	*Xylocarpus moluccensis*	✓		✓
6.	*Sonneratia caseolaris*	✓	✓	
7.	*Avicennia officinalis*	✓		✓
8.	*Avicennia marina*	✓		✓
9.	*Bruguiera gymnorhiza*		✓	
10.	*Ceriops tagal*		✓	
11.	*Lumnitzera littorea*		✓	
12.	*Lumnitzera racemosa*		✓	
13.	*Phoenix paludosa*			✓
14.	*Excoecaria agallocha*			✓
15.	*Acrostichum aureum*			✓
16.	*Nypa fruticans*			✓
17.	*Heritiera littoralis*			✓
18.	*Aegiceras corniculatum*			✓
19.	*Acanthus ilicifolius*			✓

During the study, three distinct zones were consistently seen, viz., Water front Zone, Middle Zone and Landward Zone.

Presence = ✓

Table-3 : Mangrove occurrence in different forest ranges of Middle Andaman Forest Division

S.No	Name of the Species	Bajalungta	Bakultala	Rangat	Betapur	Long Island
1.	*Rhizophora apiculata*	+++	+++	+++	++	+++
2.	*Rhizophora mucronata*	+++	+++	+++	++	+++
3.	*Bruguiera gymnorhiza*	+++	+++	+++	++	+
4.	*Ceriops tagal*	+++	+	+++	+++	+++
5.	*Phoenix paludosa*	+++	++	+++	++	+++
6.	*Avicennia officinalis*	+++	+	+	+	++
7.	*Avicennia marina*	+++	+	++	+++	++
8.	*Excoecaria agallocha*	++	++	++	+	++
9.	*Acrostichum aureum*	+++	++	++	+	+
10.	*Lumnitzera littorea*	+++	+	+	+	+++
11.	*Xylocarpus granatum*	+	+	++	---	---
12.	*Xylocarpus moluccensis*	+	+	+	---	---
13.	*Nypa fruticans*	+	---	---	+++	---
14.	*Heritiera littoralis*	+	++	++	+	+
15.	*Aegiceras corniculatum*	++	+	+	---	---
16.	*Sonneratia alba*	+	+	+	---	+
17.	*Sonneratia caseolaris*	---	+	+	+	---
18.	*Acanthus ilicifolius*	+	+	+	+	+
19.	*Lumnitzera racemosa*	+	+	+	+	+

+++ = Abundant ; ++ = Common; + = Rare; --- = Absent.

To conduct regeneration survey in each forest range 10 representative sample plots of the size 250 x 4 m were selected at different locations to cover all the species and their associations. Longer centre line of the linear plots was assumed as a transect and 2 x 2 m size quadrants were laid down on the left and right side of the central line at an interval of 5 m. Thus a total of 35 quadrants were laid down in each plot, and 100% enumeration of seedlings/saplings was done in each quadrant. These seedlings were divided into four different height classes, viz., 0-30 cm, 31-60 cm, 61-90 cm, 91-120 cm and data was recorded accordingly. Natural regeneration of a species was considered good if its minimum three seedlings were found present in each of the 4 height classes in at least one sample plot. Similarly natural regeneration of a species was considered moderate if its minimum two seedlings were found present in at least any three of the four height classes, in at least one sample plot. All other categories of natural regeneration were put under poor (Table-4).

For *Acanthus ilicifolius* and *Acrostichum aureum*, number of plants in 0-30 cm height class were only considered for judging the state of natural regeneration as the height of the mature plant in the above species seldom exceeds 60 cm.

Some observations on Mangroves

1.a) Nineteen important mangrove species are listed in descending order of abundance in Table-1. All along the estuaries and creeks continuous strips of *Rhizophora* can be seen towards water front side. *Rhizophora apiculata* is most abundant and occurs almost in pure patches. Pure patches of *Rhizophora mucronata* are much less compared to *Rhizophora apiculata*. At some places these two species also co-

Table-4 : Comparative state of natural regeneration of mangroves in different ranges of Middle Andaman Forest Division

S No	Name of the Species	Bajalungta	Bakultala	Rangat	Betapur	Long Island
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.	*Rhizophora mucronata*	G	G	P	P	G
3.	*Bruguiera gymnorhiza*	P	G	M	M	P
4.	*Ceriops tagal*	G	P	G	G	G
5.	*Phoenix paludosa*	G	G	G	G	G
6.	*Avicennia officinalis*	G	G	---	---	G
7.	*Avicennia marina*	G	G	G	M	G
8.	*Excoecaria agallocha*	M	G	M	P	P
9.	*Acrostichum aureum*	G	G	G	G	---
10.	*Lumnitzera littorea*	G	G	P	P	G
11.	*Xylocarpus granatum*	P	P	P	---	---
12.	*Xylocarpus moluccensis*	---	P	P	---	---
13.	*Nypa fruticans*	G	---	---	P	---
14.	*Heritiera littoralis*	P	G	P	P	P
15.	*Aegiceras corniculatum*	G	---	---	---	---
16.	*Sonneratia alba*	M	P	P	---	M
17.	*Sonneratia caseolaris*	---	P	P	M	---
18.	*Acanthus ilicifolius*	---	G	---	---	---
19.	*Lumnitzera racemosa*	---	P	P	---	G

G = Good Natural Regenaration; M = Moderate Natural Regeneration;
P = Poor Natural Regeneration; --- = Species not significant in the range from occurrence point of view.

exist. Stands consisting of tall *Rhizophora* trees about 30-35 m high with cylindrical bole are common in Middle Andaman. *Rhizophora* is also important from commercial point of view.

1.b) Tall trees of *Bruguiera gymnorhiza* are abundant and also important from commercial point of view. Mature trees vary in height from 25-35 m.

1.c) *Ceriops tagal* is a small sized tree and occurs in abundance in various parts of Middle Andaman. There are areas in the division where there is exceptionally high concentration of this species. Although the tree is not very important from commercial point of view, it yields little fuel-wood to meet small demand of local people.

1.d) *Avicennia officinalis* and *Avicennia marina* trees occur in a scattered manner but at few places some big patches of *Avicennia* can be seen. At most places *A. marina* plants have been adversely affected due to cattle pressure as its leaves are palatable. At places trees with large girth can be seen which can commercially yield fire-wood. Hollowness is common in overmature trees.

1.e) *Sonneratia alba* and *Sonneratia caseolaris* are rarely found in Middle Andaman.

1.f) Towards landward side *Phoenix paludosa*, *Excoecaria agallocha*, *Acrostichum aureum*, *Heritiera littoralis* are very common.

1.g) *Lumnitzera littorea* is common in Middle Andaman but *Lumnitzera racemosa* is rare. *L. littorea* is found exceptionally abundant in some areas.

1.h) *Aegiceras corniculatum* is rare in Middle Andaman except in some places like Uttara where large number can be seen in a limited area.

1.i) *Xylocarpus granatum* and *Xylocarpus moluccensis* trees are fairly common and found both towards waterfront and landward side. As these trees are found scattered, they are not important for commercial exploitation.

1.j) *Nypa fruticans* occurs towards landward side. The palm is not evenly distributed in Middle Andaman. There are areas like Dhaninallah where the species occurs in pure patches. The species is under pressure as its leaves are most preferred for thatching and local people eat kernel of young fruit.

Recommendations

1) Biotic interference should be checked by increasing protection and educating people, to facilitate natural regeneration and further growth of Mangroves.

2) It was observed during the study that natural regeneration is not coming up where canopy is closed. Therefore, wherever necessary canopy should by carefully opened to a minimum extent so that sun light may reach the ground and promote natural regeneration.

3) Artificial planting should be taken up in all degraded mangrove areas for its quick restoration. Reasons for degradation of the area should be analyzed and their non-repetition should be ensured.

4) New and useful Mangrove species should be introduced in a particular area after conducting experimental trials, for example *Nypa fruticans* which is mainly confined to Betapur Range may be tried for planting in suitable areas of other ranges as the leaves of this palm are in heavy demand by the local people for thatching purposes.

5) There are many Mangrove species which are rare. Special efforts should be made to multiply these species and save them from extinction.

6) There are some species like *Kandelia rheedi* which are not at all found in Middle Andaman. Experimental trials should be conducted for introduction of such species.

7) Specialized training should be imparted to officers and staff for better conservation and management of Mangroves.

8) Research work on Mangroves should be promoted for better resource management. Inter-organizational co-operation among various organizations working on the subject will be useful for exchange of ideas, information, etc.

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References

Dagar, J.C., Mongia, A.D. and Badhopadhyay, A.K. (1991). *Mangroves of the Andaman and Nicobar Islands*. Oxford and IBH Publishing Company. pp. 54-112.

Balachandra, L. (1988). A comprehensive account of the Mangrove vegetation of Andaman and Nicobar Islands. *Indian Forester*. 114: 741-751.

Parkinson, C.E. (1923). *A Forest Flora of the Andaman Islands*. Shimla. M/s Bishen Singh Mahendra Pal Singh, 23-A, New Connaught Place, Dehra Dun

ARTIFICIAL REGENERATION OF MANGROVES

RAJIV KUMAR*

Introduction

Mangroves are salt-tolerant forest ecosystems of the tropical and sub-tropical inter-tidal regions of the World. Mangrove ecosystem is a group of numerous plants and animals interacting with each other and their surroundings. The Mangrove forests found in the Indian Sub-Continent are the richest as these has more than 2/3rd of the Mangrove species found in the World. Mangrove ecosystem offers numerous tangible and intangible benefits to the mankind. The ecosystem is one of the most productive coastal ecosystems of the world, which has played a crucial role in socio-economic life of the people living around Mangrove-bearing coastal areas. Mangroves play an very effective role in checking the soil erosion and in stabilizing coastlines. They also act as wind breaks and improve the climatic conditions. Mangrove forests are excellent resting and breeding grounds of fishes, Crustaceans (Prawns, Shrimps and Crabs), Molluscs, Honey Bee, birds, reptiles from which we get proteinous food material, fertilizer, honey and wax. Mangroves also provide excellent fuelwood with high calorific value and termite resistant timber. Leaves of Mangrove species *Avicennia marina* are used for fodder for milch animals. Bark of Mangrove trees and shrubs is a rich source of vegetable tannins.

Because of the economic benefits associated with the Mangroves, they were over exploited in the past, which resulted in their degradation. This indiscriminate exploitation by man has left them in varying degrees of degradation however, in the last ten years, Government of India and State governments have taken very effective steps for conservation and development of Mangroves.

Regeneration Methods

Degraded Mangrove areas can be restocked either naturally or artificially.

Natural regeneration : Success of natural regeneration varies from place to place and from species to species and it depends on various factors viz. production of abundant propagules and seeds, favourable site conditions for germination-cum-establishment, degree of biotic interference and other abiotic factors. Taking some measures like removal of weeds, debris in the area and protection from livestock can further facilitate natural regeneration. However natural regeneration offers other advantages such as reducing the cost of regeneration and also the area will have the same original vegetation without changing the composition.

Artificial regeneration : Artificial regeneration is having several advantages such as production of genetically superior stock, species selection as per choice and

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requirement, and above all, degraded areas can be quickly restored by artificial regeneration. The major objectives are to check soil erosion, enhancement of natural regeneration in future, production of fuel, fodder and timber, effective utilization of barren and unused land to increase area under Mangroves to derive maximum direct and indirect benefits, beautification of area, improvement of habitat, to support fisheries, apiculture etc. For the successful regeneration the following aspects are necessary and are discussed in the subsequent paragraphs.

Establishment of Mangrove Nursery

Objectives of establishing Mangrove Nursery are manifold and are as follows :

(a) *To raise seedlings of those Mangrove species whose propagules or seeds can not be planted directly for successful regeneration* : Generally, Mangrove species with long propagules are only taken for direct planting like *Rhizophora* and *Kandelia*. Other species, which either produce small sized propagules or seeds, are generally chosen for raising seedlings in the nursery for better plantation results.

(b) *Production of tall seedlings* : Nursery can be used for raising tall seedlings to meet special objectives. For example in Barnacle (cone shaped shell animal) infested area, it is recommended to plant tall seedlings so that growing shoots of tall seedlings remain above the level of high tide. Barnacles cannot attack the portions above water level.

(c) *Multiplication of rare Mangrove species* : Seeds or propagules of rare and endangered species can be collected and multiplied in the nursery under intensive care for eventually planting out the seedlings raised in the nursery. For example *Ceriops tagal* is found at only one place in Goa near Keri along Terekhol estuary. This species can be multiplied in the nursery to save it from extinction.

(d) *For education and awareness* : Mangrove nursery can be established near a city or town or village to educate the students and others for spreading the awareness among them.

(e) For conducting research experiments.

(f) *Stocking* : To keep stock of seedlings for planting when propagules are not available naturally. Mangrove propagules used for direct planting are not available throughout the year. Therefore nursery stock can be used for plantation when propagules are not available naturally.

Location of Nursery

A Mangrove nursery should be located preferably near the estuary in the low lying areas of the sea, which get inundated during the high tide. This type of location ensures automatic watering of the Mangrove seedlings twice a day during the high tide. The site should be close to the planting site as for as possible so as to minimise the cost of transportation of seedlings from nursery to the planting site. It may not be possible to raise all the Mangrove species in one area as the salinity of water varies from place to place. Therefore, minimum of two nurseries should be established one near the mouth region where salinity is high and another in upstream region of the estuary where salinity is low. For example *Sonneratia alba* is usually raised only in high and medium salinity area whereas

Sonneratia caseolaris is raised only in low salinity area.

The nursery site should be naturally protected from biotic interference otherwise artificial protection proves costly. If the nursery is set up for the educational and awareness purposes, it should be easily accessible preferably through a road so that people may easily and conveniently visit it. Further, Nursery should be located in sheltered places so as to avoid damage form strong waves, winds etc.

Collection of Propagules, Seeds and Fruits

During fruiting season and mature and healthy propagules, seeds and fruits can be collected for planting in the field or in the nursery. The following points should be kept in mind while collecting the propagules, seeds, etc. Only mature and healthy propagules and seeds should be collected and malformed propagules should be discarded. If seeds and propagules are collected from ground, then those attacked by fungus and borers should be discarded. It is better to collect seeds and propagules from the plants, as better seed selection is possible in this case.

It is recommended that the nursery developed should be having large number of mother trees in a small compact area. All inferior trees should be removed from such areas to avoid cross-pollination with inferior trees. To collect the propagules and seeds and to plan the nursery activities, it is necessary to have knowledge about the flowering and fruiting seasons of various species and the same is given in Table 1. The flowering and fruiting seasons of many of the Mangrove species are between March to August.

Table 1

Flowering and Fruiting in Mangroves of Goa

Scientific Name	Flowering and Fruiting
Rhizophora mucronata	March-July
Rhizophora apiculata	March-July
Avicennia officinalis	May-August
Avicennia marina	May-August
Avicennia alba	May-August
Sonneratia alba	April-June
Sonneratia caseolaris	April-June
Bruguiera gymnorhiza	March-June
Bruguiera parviflora	March-June
Kandelia rheedi	March-June
Acanthus illicifolius	April-June
Excoecaria agallocha	July-August
Ceriops tagal	April-June
Aegiceras corniculatum	April-May
Derris heterophylla	May-July

Some phenological observations given in Table 2(A) provide information regarding the time taken for developing from bud to fruit. The percentage development of buds to fruits of various species is also given in the Table 2(B).

Collection of wildings

In case of Mangrove species in some areas profuse natural regeneration takes place and in a small area hundreds of naturally grown seedlings can be seen. If these seedlings are not thinned artificially, most of them die due to congestion. Therefore, wildings from such areas can be easily collected without hampering natural regeneration. While uprooting the seedlings for transplanting in the nursery or direct planting, extreme care should be taken so that root system of seedling is not damaged,

Table 2 (A)

Development of bud to mature fruit

Species	Duration
Sonneratia alba	3 months
Kandelia rheedi	4 months
Ceriops tagal	4 months
Rhizophora apiculata	4 months
Rhizophora mucronata	5 months
Avicennia officinalis	5 months

Table 2 (B)

Development of buds to fruits in percentage

Species	Percentage
Rhizophora apiculata	14.0% to 44%
Rhizophora mucronata	6.0% to 55%
Sonneratia caseolaris	66.0% to 75%
Avicennia officinalis	3.5% to 90%

Source : Dr. A.G. Untawale, Dy. Director, National Institute of Oceanography, Goa.

otherwise it may result in the death of plants.

Some countries use a specially designed corer to extract wildings of *Rhizophora* and other species. The corer has two handles and a serrated bottom to facilitate penetration into substratum. However, this method may be practicable where planting area is close to source area of wildings, otherwise this method may prove uneconomical due to high cost of transportation.

Transportation of Seeds, Fruits and Propagules

Wherever it is necessary to transport seeds/fruits/propagules, care must be taken to preserve their viability. For the purpose of transportation, propagules of *Rhizophora, Kandelia* may be kept in bundle form in horizontal position. Propagules should be kept in wet condition and may be covered with a wet jute cloth or wet grasses. Propagules should also be exposed to moderate sunlight to prevent fungal gunny bag or bamboo basket and should be kept in shade. Planting materials should be used at the earliest for better results.

Nursery Work

Nursery site should be cleaned and leveled. All the weeds, grasses and other objectionable material should be removed from the area. If necessary the area should be fenced by using appropriate type of fencing in view of local conditions.

To raise seedlings of Mangrove species in the nursery, perforated polybags of 12 cm x 20 cm size are filled with sandy/silt clay and arranged in beds of convenient size. To provide support to these filled polybags, a framework made up of bamboo splinters is used along the boundary of the individual bed. Perforated polybags are used in the nursery so as to promote interaction of water inside and outside polybags. All the nursery works are done during low tide. It is better to make separate beds for each Mangrove species.

Whenever propagules are to be planted in the polybags, they should be carefully inserted in the bags. About one-fifth portion of the propagule should be inside the soil. Deep insertion is not recommended as it may lead to breathing problem and the propagule may eventually die.

Where seedlings are to be raised from seeds, it is better to sow fruit/seed in the mother bed and transplant the seedlings when they attain a height of about 10 cm. The fruit of aviparous Mangrove species contains a well-developed seed(s) inside. The seed germinates within the fruit. Mature fruits are collected from the trees or they are collected from the banks of estuaries where they are deposited by wave action. The characteristics of mature fruits and seeds are given in Table 3(B). Healthy fruits/seeds are sown in the mother bed. Fruit/seed should be placed about 12 mm deep in the soil. Fruit automatically bursts releasing the seeds. Seeds germinate between a period from 12 to 15 days. After a month, seedlings are ready for planting in the polybags.

The seedlings do not require much care for maintenance. These are to be protected against biotic interference and weeds are periodically removed from the nursery. Survival percentage in this type of nursery work ranges from 95 to 100%. Failed polybags seedlings may be removed from the bed and replaced by another polybag seedling of the same age so as to have seedlings of same age in one bed. Generally seedlings are kept for one year in the nursery and they attain a height of 40 to 45 cm in one year and may be used for planting in the field.

Sometimes to have tall seedlings, seedlings are maintained in the nursery for two years. Seedlings should be shifted after an interval of three months in the second year so that root may not strike the ground. Wherever seedlings are to be kept for 2 years, bigger polybags may be used. It is not advisable to keep Mangrove seedlings beyond 2 years in the nursery as when roots strike the ground, stilt roots and pneumatophores start developing after which it can not be successfully used for planting purposes.

Establishment of Mangrove Plantations

While selecting the planting site, it is necessary to see that the soil substratum should be stable. If some grasses and other vegetation are present, the site may be fit for planting. The site should be sheltered to protect the seedlings against waves and wind action otherwise seedlings may be washed off. Seedlings should be planted in inter-tidal zone where they are inundated by water regularly. Seedlings should not be totally submerged into water as this may result in death of plants. Taller seedlings like *Rhizophora* etc. should be planted towards seaward and smaller ones toward landward side. Salinity of water should be checked. Availability of fresh water should also be studied.

It is also necessary to check the following additional site characteristics while selecting planting site viz. rate of siltation, nature of soil, waves and tides in the area, solar radiation, cyclones, wind, temperature of the area. Presence of pests in the area like *Acrostichum aureum*, crabs, barnacles etc., and the availability of seeds, propagules in the nearby areas should be assessed. Possibility of active cooperation from local people should be explored especially for protection of plantation from biotic interference. Naturally germinating/established species may give an idea about the suitability of species in a given locality.

Site Preparation

Very little site preparations are required for Mangrove plantations. However, some of the following site

Table 3(A)

Characteristics of mature Propagules of Mangroves species

Name of the Species	Characteristics of ripe propagule
Rhizophora mucronata	Yellowish colour about 1.5 cm wide band (abscission collar) on the upper part of the propagule adjacent to pericarp develops on maturity. As the propagule starts maturing a thin yellowish colour band starts appearing which widens slowly as the maturity increases. Mature propagules can be plucked with slight application of force. Fully mature propagules will also fall on shaking the tree or branches. When the collar reaches about 1.5cm in length, the propagule leaves the pericarp.
Rhizophora apiculata	Same as *Rhizophora mucronata*. The only difference is that the abscission collar is about 1 cm wide on full maturity.
Bruguiera gymnorhiza	On maturity the hypocotyl changes its colour from green to dark brown. Mature propagules can be easily separated from pericarp. Abscission collar is not found.
Bruguiera parviflora	Same as *Bruguiera gymnorhiza*.
Kandelia rheedi	Mature propagules develop a yellowish abscission collar about 1 cm at the time of full maturity. Ripe propagules can be easily separated from pericarp.
Ceriops tagal	About 1 cm wide yellowish colour abscission collar develops on maturity. On maturity propagule changes its colour from green to dark brown.
Aegiceras corniculatum	Propagules become pinkish to light brown on maturity. Mature propagules can be removed from parent tree with very little application of force.

Table 3(B)

Characteristics of mature fruits and seeds of Mangrove species

Name of the Species	Characteristics of ripe fruits and seeds
1. (a) *Avicennia alba* (b) *A. marina* (c) *A. officinalis*	As the seeds mature, wrinkles develop on seed coat and the colour changes from green to yellow.
2. (a) *Sonneratia alba* (b) *S. caseolaris*	On maturity fruit changes its colour from light green to dark green. Mature fruits can be easily broken by application of little force releasing the seeds.

preparation works may be taken up if necessary. Weeds and debris should be removed from the planting site. If *Acrostichum aureum* is present, it should be removed by cutting or uprooting. Big plantation patch may be divided into smaller block with suitable inspection paths. Protection of planting site should be ensured. If the proposed planting site is one the landward side, the soil may be highly acidic due to oxidation of iron sulphide in the soil. In such cases soil should be well flushed by the tidal and fresh water to remove the toxic chemicals from the soil and to restore suitable conditions in the soil for planting purposes.

Factors for selection of Mangrove species for planting

It is necessary to select the right choice of species for successful planting and establishment. While selecting the species for planting the following points should be considered.

(a) Availability of particular seeds and propagules.

(b) *Natural zonation, Tidal inundation and soil type.* For example in Goa the Mangroves do not occur in seashore. They occur only in riverine areas viz. river mouth region and in upstream region. The soil type, tidal inundation characteristics, naturally occurring Mangroves in the region and the species recommended for planting for both the regions are given in Table 4. This will be useful in chalking out a suitable planting programmes where planting is necessary.

(c) *Salinity* : Salinity is a major guiding

Table 4

Natural Zonation in Mangroves of Goa Riverine Mangroves

Parameters	River mouth region		Upstream region	
	Riverside region	Landward region	Riverside region	Landward region
Soil type	Clayey sand to sandy clay	Silty clay	Clayey sand to sandy clay	Silt clay
Tidal inundation characteristics	Inundated daily even during neap tides	Inundated only during high tides	Tides have little influence in the up stream region. Fresh water run-off has its influence in the region	
Naturally occurring Mangrove species	*R. mucronata* *R. apiculata* *A. officinalis* *A. marina* *Sonneratia alba* *Ceriops tagal.*	*B. gymnorhiza* *B. parviflora* *Acanthus ilicifolius* *Derris heterophylla* *Excoecaria agallocha*	*A. officinalis* *A. marina* *Kandelia rheedi* *Sonneratia caseolaris* *Acanthus illicifolius*	*Excoecaria agallocha* *Aegiceras corniculatum* *Acrostichum aureum* *Derris heterophylla*
Recommended Species for planting	*R. mucronata* *R. apiculata* *A. officinalis* *A. marina* *Sonneratia alba* *Ceriops tagal*	*B. gymnorhiza* *B. parviflora* *Excoecaria agallocha*	*Kandelia rheedi* *Sonneratia caseolaris* *A. officinalis* *A. marina*	*Excoecaria agallocha* *Aegiceras corniculatum*

factor while selecting a species for planting, since most of the species do not come up well in all saline zones. Table 5 provide the general occurrence of Mangrove species in various salinity zones of Goa.

(d) Aim of plantation programme.

Plantation techniques for Mangroves

Mangrove plantation work is being carried out in Goa in the degraded Mangrove areas to increase the extent of Mangrove forests. Before taking up the planting work, site is selected with care. In the areas of relatively higher salinity *Rhizophora mucronata, Avicennia marina, Bruguiera parviflora* and *Sonneratia alba* have shown good growth results. In the areas of relatively lower salinity *Rhizophora apiculata, Avicennia officinalis, Kandelia rheedi*, and *Sonneratia alba* have shown good growth results.

Natural Mangroves species present in the vicinity of the planting site also guide us regarding the suitability of the particular Mangrove species on a particular site. At the same time we should go for detailed study of the planting site and if it is found that site is suitable for the introduction of a new species which is not pre-existing in the area, it may be taken up for planting. This will ensure enrichment of Mangrove plantation with different species. It is always better to introduce a new species in a smaller area to watch its performance so as to avoid financial loss, in case of failure due to some unforeseen factor.

In most of the places, area available for planting on both the banks of the

Table 5

General occurrence of Mangrove species in various salinity zones of Goa

Name of the species	High salinity zone (31-40%)	Medium salinity zone (21-30%)	Low salinity zone (11-20%)	Very low salinity zone 2-10%)
Rhizophora mucronata	+	+	+	
Rhizophora apiculata	+	+	+	
Avicennia officinalis	+	+	+	+
Avicennia marina	+	+	+	
Avicennia alba	+	+	+	
Sonneratia alba	+	+	+	
Sonneratia caseolaris			+	+
Bruguiera gymnorhiza	+	+	+	
Bruguiera parviflora	+	+		
Kandelia rheedi		+	+	+
Excoecaria agallocha	+	+	+	+
Ceriops tagal	+	+		
Aegiceras corniculatum		+	+	
Acanthus illicifolius	+	+	+	+
Derris heterophylla	+	+	+	+
Acrostichum aureum			+	+

+ indicates the species occurrence

estuaries in Goa is marked by two conspicuous zones with their boundary running along the estuary. First zone is that which is away from the center of the river and characterised by the presence of pneumatophores, grasses etc. The second zone is closer to the center of the river/ estuary and devoid of any vegetation. It is only deposition of sandy/silt clay on the banks.

In the past planting of Mangroves was tried in both these zones and it was observed that survival percentage in the first zone is 80% or more while in the second zone survival percentage varies from 5-10%. In the first zone pneumatophores and/or grasses bind the soil particles together and reduce the resultant impact of wave action on individual young propagules/seedlings thereby help the young seedlings in their establishment. In the second zone soil is loose and wave action is much stronger as compared to first zone, therefore, young seedlings of Mangrove do not get proper environment for their establishment. Based on our past experiences it has now been decided to take up planting work in the first zone only. Planting technique for Mangrove species may be divided into two groups based on their mode of regeneration, namely viviparous and aviparous species.

(a) *Planting of viviparous Mangrove species* : Viviparous Mangrove species like *Rhizophora, Ceriops, Bruguiera* and *Kandelia* given rise to propagules of these species are collected without damaging the radicle during April-July for directly planting out. Mature propagule is one, which shows development of a band of pale tissues near the fruit wall. Espacement in the plantation varies with the species, pre-existing vegetation on the planting site, expected survival rate etc. For example spacing will be more in the case of planting of bigger tree species like *Rhizophora mucronata*. Spacing should be less in case of small tree species like *Kandelia rheedi*. To ensure best results the propagules should be planted at the earliest after collection. While planting, propagules should not be inserted very deep in the soil. It should be inserted to a depth that is enough to prevent it's falling down. In Goa propagule is planted 4-8 cm deep in the soil depending upon the size of the propagules. No special care is required after the planting except protection from the biotic interference.

(b) *Planting of Aviparous Mangrove species* : Seedlings of aviparous genus like *Avicennia* and *Sonneratia* are raised and maintained in the nursery till they attain the age of one year. By this age average height of seedlings reaches 40-45 cm and these may be planted any time during the year. In Goa these seedlings are being used for plantation when the propagules of viviparous Mangrove species are not available. The seedlings are transported from nursery site to the planting site by boat. While transportation care should be taken to avoid damage/disturbance to the root system. Before planting the Mangrove seedlings in the pit of appropriate size, the polythene bag is removed by using sharp blade/knife to cause minimum disturbance to the root system.

SUMMARY

Mangroves are one of the most productive ecosystems of the tropical coastal areas of the world and are fragile in nature. Despite their ecological significance such as stabilizing the coastal shorelines, guarding the landmass from tidal surges, cyclones, high velocity winds;

checking the advancement of sea etc., Mangroves are subjected to unabated exploitation for economic gains. This causes severe stress to its hygiene and survival. In this process of economic exploitation, we lose many areas and it is difficult to regenerate areas, which are highly degraded. For the proper management and eco-restoration of Mangroves, artificial regeneration is a must to augment areas successfully with right choice of species. Artificial regeneration is utmost important in areas where natural regeneration is a failure or inadequate. This paper describes the various aspects of artificial regeneration from nursery to planting out and analyses the issues involved therein. This is an outcome of the author's observations based on studies conducted on Mangroves in Goa and Middle Andaman.

वायुशिफों का कृत्रिम पुनर्जनन

राजीव कुमार

सारांश

वायुशिफ संसार के उष्ण सागरतटीय क्षेत्रों की सर्वाधिक उत्पादक परिस्थिति - संहतियों में आते हैं और प्रकृत्तितः वे बहुत भंजनशील हैं । अपनी पारिस्थितीय विशिष्टताओं के बावजूद जैसे कि सागरतटीय तट रेखा को स्थिर बनाना, भूमिपुंज की ज्वारभाटा उछाल, बवण्डरों, अधिक वेगवती हवाओं से रक्षा करना, समुद्र को भूमि की ओर आगे बढ़ने से रोकना आदि, इन वायुशिफों का अधिक लाभ प्राप्ति के लिए भी निरन्तर समुपयोजन किया जाता आ रहा है । ऐसा होने से इनके स्वास्थ्य और अतिजीविता पर भारी दबाव पड़ रहा है । आर्थिक समुपयोजन की प्रक्रिया में बहुत सारे क्षेत्र हमारे हाथ से सदा के लिए निकल जाते हैं क्योंकि बहुत अधिक व्याहसित हो जाने से इनको पुनर्जनित करना कठिन है । वायुशिफों का समुचित प्रबन्ध और ऐसे क्षेत्रों का पारिस्थिकीय पुनरुद्धार करने के लिए सही वायुशिफ जाति का चुनाव कर ऐसे क्षेत्र में सफलता पाने के लिए कृत्रिम पुनर्जनन अपनाना ही होगा । ऐसे क्षेत्रों में जहाँ प्राकृतिक पुनर्जनन सफल नहीं रहा अथवा अपर्याप्त हुआ है वहाँ तो कृत्रिम पुनर्जनन कराना अत्यधिक महत्वपूर्ण है । इस अभिपत्र में रोपणी से आरम्भ कर वन भूमि में पौधे लगाने तक कृत्रिम पुनर्जनन के विविध पक्षों का वर्णन दिया गया है और इसके अन्तर्गत जो - जो प्रश्न उठते हैं उनका विवेचन किया गया है । यह अभिपत्र लेखक के उन अध्ययनों में लिए गए प्रेक्षणों का परिणाम है जो उसने गोवा और मध्य अंडमान के वायुशिफों में किए हैं ।

References

Anon. (1987). *Mangroves of India* : Status Report, Ministry of Environment and Forest, Govt. of India, New Delhi. pp. 52-55.

Anon. (1991). *Mangrove Management plan for Goa*. Report of Research and Utilisation Division, Forest Department, Goa. pp.,12-21.

Kumar, Rajiv (1995). Mangrove Plantations in Goa, *Indian Forester*, **121** (1) :3-6.

Untawale, A.G. (1986). *How to grow Mangroves*. Field Guide Book. National Institute of Oceanography, Published by WWF-India, Bombay. pp. 1-9