CHAPTER-1
MANGROVES-AN INTRODUCTION

Coastal ecosystem provides a wide array of goods and services. They host the world's primary ports of commerce; they are the primary producers of fish, shellfish, and seaweed for both human and animal consumption; they are also a considerable source of fertilizer, pharmaceuticals, cosmetics, household products, and construction materials.

1.1 Mangroves and its importance: Mangroves line 8% of the world's tropical coastlines, covering a surface area of approximately 181,000 km² (Spalding et al., 1997). They also might occur along the subtropical regions. Adapted to conditions of varying salinity and water level, the mangroves flourish in sheltered coastal areas such as river estuaries. Mangrove swamps are one of the richest and most productive areas and form the base for the food chain in the sea and coastal waters. They are crucial to the productivity of tropical fisheries because they act as spawning grounds for a wide range of fish species. They also provide local communities with timber and fuel wood and help to stabilize coastlines. Mangroves are present on the shores of East and West Africa, South and South East Asia, Oceania, north Australia and east and west coasts of America. According to Quasim and Wafar (1990) among the tropical marine ecosystems mangroves rank second in importance only to coral reefs in terms of gross productivity and sustained tertiary yield.

Mangroves protect shorelines from damaging storm and hurricane winds, waves, and floods. Mangroves also help prevent erosion by stabilizing sediments with their tangled root systems. They maintain water quality and clarity, filtering pollutants and trapping sediments originating from land. Mangrove serves as valuable nursery areas for shrimp, crustaceans, mollusks, and fishes. They also filter water, trap the silt and contribute to clarity of water.

In addition mangrove trees have been utilized as a renewable resource. Harvested for durable, water-resistant wood, mangroves have been used in building houses, boats, pilings, and furniture. Tannins and other dyes are extracted from mangrove bark. Leaves have been used in tea, medicine, livestock feed, and as a substitute for tobacco for smoking.

1.2 Mangrove species in Karnataka: Mangrove swamps develop only where coastal physiography and energy conditions are favorable. Mangroves develop best in the region, experiencing abundant rainfall, evenly distributed throughout the year and when the climate is very much regular. The coastal Karnataka is a region of high humidity. The rainfall here varies from 2500 mm to slightly over 3000 mm, most of it seasonal during June-September, the period of the South-West Monsoon. Karnataka coast soil is a mixture of laterite rock and clay.

Table 1: True Mangroves of Karnataka:

Sl. No.	Family	Species
1	**Acanthaceae**	*Acanthus ilicifolius*
2	**Combretaceae**	*Lumnitzera racemosa*
3	**Euphorbiaceae**	*Excoecaria agallocha*
4	**Myrsinaceae**	*Aegiceras corniculatum*
5	**Poaceae**	*Porteresia coarctata*
6	**Rhizophoraceae**	♦ *Bruguiera cylindrica* ♦ *Bruguiera gymnorrhiza* ♦ *Kandelia candel*

		♦ *Rhizophora apiculata* ♦ *Rhizophora mucronata*
7	**Sonneratiaceae**	♦ *Sonneratia alba* ♦ *Sonneratia caseolaris*
8	**Verbenaceae**	♦ *Avicennia marina* ♦ *Avicennia officinalis*

Table 2: Mangrove associates that have close proximity to mangrove vegetation:

Mangorve Associates
Barringtonia spp., Caesalpinia crista, Cerbera manghas, Clerodendrum inerme, Cyperus malaccensis, Derris trifoliata, Erythrina variegata, Hibiscus tiliaceus, Morinda citrifolia, Pandanus sp. Salvadora persica, Thespesia populnea, Acacia auriculiformis Borassus flabellifer Ficus racemosa, Casuarina equisetifolia, Odina wodier, etc.

1.3 Mangrove distribution

1.3.1 Mangrove distribution in Karnataka: Karnataka has a coastline of over 320 kilometers. Fourteen rivers and several small rivulets, which originate in the Western Ghats cut across the coast to join the Arabian Sea. Towards the coast, the salt water tides from the sea travel several kilometers interior through the river mouths providing congenial habitats for mangroves. Most mangroves are of the fringing type in linear formations along the river or estuarine banks. Where the estuaries are wider, especially in Swarna-Sita-Kodi, Gangoli, (towards the mouth of Haladi-Chakra-Kollur rivers), Aghanashini and Kali there are several remarkable locations for mangroves.

1.3.2 Mangroves of India: India has only 2.66% of the world's mangroves, covering an estimated area of 4,827 sq. km. However, the Sunderbans in the delta of Ganges river has the world's single largest mangrove forest, covering 420 sq. km. Out of India's total area under the mangroves; about 57% are found on the East Coast, 23% on the West Coast and remaining 20% on the Andaman and Nicobar Islands. The West Coast mangroves belong to the backwater-estuarine types (Krishnamurthy, 1993; Subramanaian, 2000; Venkataraman, 2003). The East Coast rivers with more deltaic zones have greater mangrove development than the narrower mouths of West Coast rivers, which may be many times rocky too.

According to the Government of India (1987), India lost 40 percent of its mangrove area in the previous century. The National Remote Sensing Agency (NRSA) recorded a decline of 7,000 ha of mangroves in India within the six-year period from 1975 to 1981. In Andaman and Nicobar Islands about 22,400 ha of mangroves were lost between 1987 and 1997. In Karnataka the mangrove area has declined from 6000 ha in 1987 to mere 300 ha in 1997 (Table 3). The State Government had, since then adopted commendable steps to replant suitable areas with mangroves. The major reasons for mangrove decline could have been large-scale disturbances due to shrimp farming and reclamation for mangrove habitats for other activities.

Table- 3: Area distribution of mangroves in India (thousand ha)

State/Union territory	Government of India, 1987	Government of India, 1997
West Bengal (Sundarbans)	420	212.3
Andaman and Nicobar Islands	119	96.6
Maharashtra	33	12.4
Gujarat	26	99.1
Andhra Pradesh	20	38.3

Tamil Nadu	15	2.1
Orissa	15	21.1
Karnataka	6	0.3
Goa	20	0.5
Kerala	Sparse	Nil
Total	**674**	**482.7**

Along the Indian coast there is considerable variation in the rainfall. Along the west coast the rainfall ranges from about 3000 mm along the coast of Kerala and Karnataka down to 400 to 600 mm towards the north of Gujarat coast. Along the east coast the rainfall ranges from mere 90 mm at the Gulf of Mannar to 1900 mm in the Sunderbans. The Andaman and Nicobar Islands receive up to 3200 mm of rainfall. Both the Sunderbans and the Andaman and Nicobar are richest centres of Indian mangroves.

1.3.3 Global distribution: The world's major mangrove areas are found in regions where the atmospheric temperatures are ideally between 20°C and 35°C. Mangroves develop best in the region experiencing abundant rainfall evenly distributed throughout the year. Mangroves are found along many of the coasts in the tropics and subtropics. However, the total area of mangroves in the world is not well known. Recent estimates range from 16.5 million ha (FAO, 1994), 18.1 million ha (Spalding et al., 1997) to 19.9 million ha (Fisher and Spalding, 1993). In many of these studies, countries with small areas of mangroves have been excluded.

The Indo-Malaysian area is considered as the cradle of evolution of mangrove ecosystems, from where they spread to other regions of the tropics. At present the Indo-Pacific region, especially Southeast Asia, is known for its luxuriant mangroves.

Details regarding some of the countries with large areas under mangroves are given in the following table:

Table 4: Details of countries leading in area under mangroves (WRI- 2000)

Region	Country	Current extent (km²)
Africa	Guinea-Bissau	3,150
	Tanzania	2,120
	Gabon	1,150
	Angola	1,100
Latin America	Mexico	5,315
	Panama	1,581
Asia	Indonesia	24,237
	Myanmar	4,219
	Vietnam	2,525
	Malaysia	2,327
	Thailand	1,946
	Pakistan	1,540
	Philippines	1,490
Oceania	Papua New Guinea	4,627

1.4 Decline of mangroves: The main threat to mangroves throughout the world is their over-exploitation by man. Development along the coastline often results in the removal of

mangroves by dredging for marinas or filling for construction. This has damaging effects on adjacent habitats, such as coral reefs and seagrass beds, as well as on the fish and shellfish that rely heavily on mangroves for the completion of their different life stages. The destruction of mangrove forests will decrease biodiversity within these areas, increase coastal erosion, storm impacts and decrease fisheries production. It is therefore very important that mangrove lagoons are protected and conservation methods be implemented to ensure their continued health.

Historical records indicate that the original extent of mangrove forests has declined considerably under pressure from human activity. National proportions of original mangrove cover lost vary from 4 to 84%, with the most rapid losses occurring in recent decades. Overall, as much as half of the world's mangrove forests may have been lost in the recent decades (Kelleher et al., 1997).

Whereas mangroves can protect the coast from natural calamities, such calamities can create considerable damage to mangroves themselves. Vast stretches of mangroves were destroyed along the shores of Andaman & Nicobar Islands during the tsunami of December 24, 2004.

During the recent times, the estuaries and lagoons, home to the mangroves, have been subjected to ruthless damage and even total destruction due to anthropogenic pressures such as population explosion, industrialization, construction of dams and barrages upsetting the free flow of water, siltation of mangrove habitats due to upstream deforestation, dredging operations, aquaculture etc (Venkataraman, 2003).

Coastal Karnataka is one of the better-developed geographical areas of the State with high degree of economic development and density of population. The settlements in the coastal region consists 22 urban agglomerations and 1044 villages. The region supports high degree of agricultural and horticultural activities, fishing and aquaculture, sand and shell mining, industry, harbour development, trade and transport etc. which naturally have their toll on coastal ecosystems, including mangroves. The Project Seabird Naval Base has converted 32 sq. km of land, including some of the mangrove areas, into a highly man-modified complex of artifacts.

According to the *State of the Environment Report and Action Plan, 2003* (Department of Forest, Ecology and Environment, Government of Karnataka) "Many coastal depressions in the vicinity of mangrove habitats are filled with mud scooped from lagoons to cultivate coconut plantations. The coir retting carried out mainly in mangrove cleared areas, is a microbial process and causes pollution of water, air and soil, which in turn, affects the marine resources, quality of estuarine banks and nearby beaches." Some of the major reasons for the decline of mangroves, especially along the central west coast, including that of Karnataka are:

- Over-exploitation or deforestation of mangroves for fuel and fodder
- Reclamation of mangrove swamps
- Sand and shell mining
- Grazing and trampling by livestock
- Damages to saplings from native crafts and fishing activities
- Bund and road making
- Dumping of rubbish and solid waste into the swamps
- Impact of dams and barrages

1.5 Estuaries: The coastal tract is a great meeting place of ecosystems. Here the land meets the sea and the waters of the rivers mingle with the tides of the oceans, giving rise to yet another ecosystem, the estuary. The word "estuary" refers to a river mouth or coastal bay where the salinity is intermediate between sea and fresh water, and where tidal action is an important physical regulator. The low-lying areas of the coast form littoral marshes and backwaters. The sandy and rocky beaches, the intertidal zone and the mudflats add to the diversity and complexity of the coastal zone. Coastal zones have tremendous biological diversity and productivity. From time immemorial the coastal zones have been centers of great human activity. Coastal ecosystems provide a wide array of goods and services: they host the world's primary ports of commerce; they are the primary producers of fish, shellfish, and seaweed for both human and animal consumption; they are also a considerable source of fertilizer, pharmaceuticals, cosmetics, household products, and construction materials (Odum, 1963; WRI, 2000).

Coastal ecosystems harbour a wealth of species and genetic diversity, store and cycle nutrients, filter pollutants from inland freshwater systems and help to protect shoreline from erosion and storms. The beauty of the coastal ecosystems makes them a magnet for the world's population, and is the greatest draw for tourism (WRI, 2000). The coastal regions are defined as "the intertidal and sub-tidal areas above the continental shelf (to a depth of 200 m) and adjacent land area up to 100 km inland from the coast". The bulk of the world's marine fish harvest- as much as 95% is caught or reared in coastal waters (Sherman, 1993).

The mangroves make an important constituent of coastal ecosystems, which also include coral reefs, tidal wetlands, seagrass beds, estuaries, peat swamps and a variety of other habitats. Each of these provides its own distinct set of goods and services. The coastal ecosystems are knit together to form one fabric of life that is in continuity with the deep ocean and the land. Therefore the mangroves *per se*, the subject of this report, is not to be treated as an independent entity but as constituting a vital component of a holistic super-ecosystem. The very fact that almost 40% of the world's population lives within 100 km of a coastline, that is only 22% of the total landmass, highlights the importance of the coastal zone. Fish and shellfish provide about one-sixth of the animal protein consumed by people worldwide. A billion people, mostly in developing countries, depend on fish for their primary source of protein (WRI, 2000).

1.6 Structural and functional attributes

Mangrove habitats have relatively low levels of species richness compared with other high biomass tropical habitats like rain forests and coral reefs. But the mangroves are valued not for their species numbers but for their broad range of structural and functional attributes, which promote their survival in relatively harsh conditions of the intertidal zone. The community as a whole shares a number of highly specialized adaptations allowing them to cope up with regular tidal inundation of roots and sediments by salty waters. The adaptations that the community collectively has are:

- Breathing roots to cope up with anaerobic conditions
- Support structures such as buttresses and stilts (props)
- Low water potential and high intracellular salt concentration to maintain favorable water relations in saline environments
- Foliage salt excretion to remove excess salt from sap
- Water conservation in leaves to cope up with high salinity stress
- Buoyant viviparous propagules.

(Ref: Duke et al., 1998)

1.6.1 A jungle of roots: The mangrove formation is characterized by aerial roots of varied kinds, which together entangle to form an almost impenetrable barrier. This barrier for human entry is however highly beneficial for a number of faunal elements, which escape the depredations of their enemies, including the man. Here the boatman cannot row his boat and the fisherman cannot cast his net. Many mangrove trees and shrubs are seen standing on stilt like aerial roots, in shallow parts of the coastal waters. Members of the community, in general, give the appearance as if they are walking in the water; so they are sometimes known as "walking trees". (eg. *Rhizophora mucronata* -Figure 1.1). Around the tree trunk of some mangroves are pencil like, peg like or cylindrical roots of varied lengths that grow vertically into the air above the level of mud and water. These roots are studded with numerous pores or lenticels, visible to the naked eye, which function as ventilators helping gaseous exchange of that part of the root system, permanently buried in the anoxic conditions of the swamp (Figure 1.2 and 1.3); they are appropriately named as 'pneumatophores' (literally meaning 'lung roots') or 'breathing roots'. *Avicennia* spp. and *Sonneratia* spp. are well known for there breathing roots.

The breathing roots of *Bruguiera* spp., are knee like protrusions that emerge from the mud; the exposed portions of these knee roots are studded with lenticels (Figure 1.4). *Bruguiera* has also some amount of stilt root development (Figure 1.5). The base of the stem is flattened into buttresses in the older trees. *Kandelia candel* also produces buttresses and stilt roots that are closely placed to the main stem (1.6). The buttresses and stilt roots provide also additional support to the trees, in addition to ventilating the buried parts of the plants. *Excoecaria agallocha*, yet another tree, has prolific development of serpentine aerial roots (Figure 1.7).

1.7 Trees giving birth to seedlings (vivipary)

If the seeds of typical land plants get submerged in water they fail to germinate, due to lack of oxygen. On the other hand several mangroves, especially members of the family Rhizophoraceae, exhibit precocious germination of the seeds, even while the fruit is still attached to the parent tree. The seed germinates within the fruit, the radicle or root tip penetrates through the fruit wall, and a long, green, spindle shaped seedling emerges from the fruit. The stem tip is still within the fruit. These seedlings, or rather propagules, dangling in good numbers from the parent tree, distinguish the mangrove vegetation from other kinds. The propagules, when fully grown, attain length of few cms to almost a meter, depending upon the species. On maturity they detach from the parent tree and vertically fall into the soft, waterlogged swamp. Within hours branch roots start emerging and the propagules establish as independent daughter plants. Longer the propagule, deeper the water the species can colonise. This method of reproduction is known as 'vivipary' literally meaning 'giving birth'. Propagules of *Rhizophora mucronata*, species most common along Karnataka coast, are shown in Figure 1.8. Other genera of the family such as *Bruguiera*, and *Kandelia* also exhibit vivipary. If the propagules fall during the high tide they might be dispersed elsewhere by the water currents. The mangrove species, which do not exhibit vivipary usually, grow towards the shallow shoreward sides.

1.8 Detritus-based self- sufficient system

The mangrove system is self-sufficient in production and utilization of food material. It is detritus based system, unlike the marine 'plankton' based system. At least 190 species of filamentous fungi are associated with mangrove habitats (Alias, 1996). Microbial organisms

like yeast and bacteria along with fungi play very important role in the decomposition of mangrove foliage, regeneration of nutrients and mineralization (http://www.indian-ocean.org/bioinformatics/mangroves/mangcd/fact.htm).

The leaves of mangroves that fall in the estuary form protein rich detritus. The detritus provides breeding and nursery grounds for the juveniles of many commercially important shrimps and fishes and becomes also food for suspension and deposit feeders and also for juveniles of a variety of bivalves, shrimps and fishes, which migrate into the mangroves for better feeding and protection. Many other lower organisms, which feed on such dead organic material, constitute the basis for food chains of the estuaries and even of the coastal sea. The litter-fall of mangrove trees (Figure 1.9) amounts to a large quantity of nutrients which reach through water beyond the mangrove swamps, even into the marine ecosystem These detritus rich mangrove areas are used by valuable fishes, prawns, crabs, oysters, shell-fish etc. for reproduction and growth. Therefore mangrove areas are of considerable economic importance for capture as well as captive fisheries ((Odum and Heald, 1975; Untawale, 1987).

Although true mangroves are limited in number, hardly exceeding 10-15 species in most places, there is tremendously rich microflora associated with mangrove habitats. Salique et al (1985) reported 7 species of Phycomucetes, 2 of Ascomycetes and 12 Deutreomycetes fungi from the Vellar-Pichavaram estuaries of Tamil Nadu. Venkatesan and Natarajan (1985) found 27 species of fungi belonging 17 genera from the root zone of *Avicennia officinalis* and 26 species from 20 genera from the root zone of *Rhizophora mucronata* in the Pichavaram mangroves. Jagtap (1985) identified 44 species of algae from 30 genera from the mangrove swamps of Goa. Bhowmik et al (1995) listed 24 strains of bacteria from the decomposed litter of Sunderban mangroves. Sadiq et al (1985) recorded 10 species of yeast in the Vellar estuary and Pichavaram mangroves.

According to Wafar et al. (1997) the energy flux from mangroves is more important for sustaining microbial food chain and nutrient regeneration than the particulate food chains directly. For increasing productivity based on mangroves, so that they attain the status phytoplankton, ratio of mangrove forest cover to the estuarine area has to be increased.

Figure 1.1: The 'Walking trees', Rhizophora mucrona on still roots

Figure 1.2. Breathing roots of Avicennia officinalis

Figure 1.3: Officinalis-part of breathing root enlarged showing lenticels (air pores)

Figure 1.4. Knee roots of Bruguiera gymnorrhiza

Figure 1.5. The stem base of Kandelia candel showing buttresses and stilt roots

Figure 1.6: The stem base of Bruguiera gymnorrhiza with stilt roots

Figure 1.7: Serpentine roots of Excoecaria agallocha

Figure 1.8: Rhizophora mucronata showing viviparous propagules

Figure 1.9: Litter fall amidst the stilt roots of Rhizophora mucronata

1.9 Mangrove habitats: The places where mangroves grow are called 'mangrove ecosystems'. Mangrove ecosystems are highly productive but very sensitive. The mangroves grow well on silty and clayey mud or on mixtures of these soils. Under the canopy of mangroves the soils undergo physical and chemical alterations. In the mangrove areas one can notice some zonation. Whereas some mangroves are found growing along the edge of water, some prefer the shallower middle zone and yet others occur only towards the drier land. Such zonation of mangroves is affected by various factors such as: frequency of flooding by tides, soil types based on structures, salinity, nutrient content, permeability and drainage (Clarke and Hannon, 1967, 1969; MaCnae, 1968), plant interaction (Jones, 1971; Karkar and Bhosale, 1985), iron influx-efflux regulatory mechanism (Walter, 1961) and animal interaction (MaCane, 1968).

Mangrove trees as well as their seeds and propagules require soft muddy substratum for growth. The mangroves grow well on silty and clayey mud or on mixtures of these soils. Under the canopy of mangroves the soils undergo physical and chemical alterations. Although mangroves are able to grow on sand, peat and coral, they develop well in muddy soils. The mangroves themselves may influence sediment composition; they may accelerate mud accretion wherever they grow.

1.9.1 Salinity of mangrove habitats

Towards the river mouths and in marine inlets the water usually will have higher salinity to the tune of 30 ppt to 40 ppt. This zone is known as 'euhaline". Such zone is colonised by *Avicennia marina, Rhizophora apiculata, R. mucronata, Sonneratia alba* etc. The zone behind is called 'polyhaline' where the wave action is less and salinity ranges from 18 ppt to 30 ppt. The substratum is sandy clay. This region is ideal for mangroves like *Sonneretia alba, Rhizophora spp., Avicennia spp., Brugiera* spp., Acanthus ilicifolius etc.

The third zone, still behind is 'mesohaline' where salinity ranges from 5 ppt to 18 ppt. It has silty clay bottom and feeble wave action. The mangroves of this zone are *Kandelia candel, Acanthus ilicifolius, Avicennia officinalis, Aegiceras corniculatum, Sonneretia caseolaris* etc. Many mangrove associate species are found in the 'oligohaline' zone where the salinity is down to 0.5 ppt to 5 ppt as a result of more freshwater influx. Plants such as *Cerbera manghas, Cyperus malaccensis, Barringtonia* spp., *Pandanus* spp. etc. tend to occur more in this region.

Some mangroves do not experience any difficulty in absorbing salt water through their roots, whereas others exclude salt while absorbing water. Mangrove species such as *Avicennia, Aegialitis, Aegiceras* and *Acanthus* absorb salt water. They have on their leaf surfaces microscopic, multicellular salt glands for salt secretion. Their leaves have some fleshiness because of water storing tissues. Salt toxicity in the leaves is avoided by diluting the internal salt levels by water storing tissues (Karmarkar, 1994). Salt excluding mangrove species do not take salt water internally. The Red mangrove (*Rhizophora* spp.) is a salt excluder separating fresh water at the root surface by creating a type of non-metabolic ultra-filtration system, but yet the salinity level of xylem sap is reported to be 10 times higher than the normal plants (http://www.nhmi.org/mangroves/phy.htm).

1.10 Mangroves and tidal amplitude: Mangroves are unique because they are a gift of the tides along the low-lying tropical and occasionally sub-tropical coasts; they occur along the margins of estuaries, deltas, and coastal and brackish tidal waters in general. There are

no mangroves where the tidal amplitude is very low (Vannucci, 2001). The place of most mangroves indeed is between Mean High Water Spring Tide (MHWST) and Mean Sea Level (MSL). There is considerable south to north variation in the tidal amplitude. It is minimal along the coast of southern Kerala. In Goa the tidal amplitude is about 1.5 to 2 meters. In the Gulf of Khambat the highest tidal amplitude is about 8-9 meters; in the Gulf of Kutch it is about 5 meters. Tides are affected during the monsoon months when there is considerable flow of fresh water into the sea.
(http://www.indian-ocean.org/bioinformatics/mangroves/mangcd/fact.htm).

1.11 The fauna of mangroves: Mangroves are rich in animal species though there are extremely few animals exclusive to mangroves. Many microfaunal species associated with mangroves are imperfectly known. Among the invertebrates are great abundance of molluscs, crustaceans and insects of a variety of orders. All orders of vertebrates, including residents and other visitors, among them mammals like dolphins, carnivores, deer and monkeys numerous kinds of resident and migratory birds, reptiles like crocodiles, snakes, amphibians and all sorts of fishes and their fry inhabit mangroves. Each mangrove stand has its typical fauna In fact the fauna of mangroves is typically opportunistic and none of the species is specially adapted to mangrove environment. Many are visitors, including the humans taking advantage of the high productivity of the mangrove system. Mangroves provide nursery grounds for juveniles of fish and crustaceans, which even come from the sea. Even camels traditionally visit certain mangrove islands like Aliabet Island in the estuary of Narmada, to feed on the grass *Porteresia coarctata* (Vannucci, 2001).

Of the different species of crustaceans associated with mangroves are *Penaeus indicus, P. merguiensis,* and *P. monodon.* The crabs are represented by *Uca* sp., *Scylla serrata, Thalassina* etc. The fishes are represented by mudskippers, carangids, clupeids, serranids, mullets, hilsa, seabass, milkfish etc. The wildlife of Indian mangrove forests is quite diverse and interesting. Apart from the famous Royal Bengal Tiger and estuarine crocodile, there are different kinds of monkeys, otters, deer, fishing cats, snakes and wild pigs. The Indian mangrove swamps are favored by a variety of birds, both migratory and resident.
(http://www.indian-ocean.org/bioinformatics/mangroves/mangcd/fact.htm).

In the Sunderban mangrove Tiger Reserve, Saha et al (1985) observed sea anemones, polychaetes, crabs, gastropods, hemi-chordates and mud skippers. Samant (1985) recorded 121 species of birds from the mangroves around Ratnagiri town. Daniels (personal communication) has furnished a list of 118 species of estuarine birds from Uttara Kannada district. Burrowing crustaceans promote growth of established trees by improving soil aeration, which reduces levels of harmful sulphides produced due to anaerobic conditions (Smith et al., 1991).

1.12 Mangrove conservation and management in India

Historically speaking India has a long tradition of conserving mangroves, both by the State as well as by coastal communities. Way back in 1892, a plan was prepared for the management of the mangroves of Sunderbans (Chaudhuri and Chaudhuri, 1994). However, such tradition started weakening due to various reasons cited earlier. In 1976 the Ministry of Environment and Forests of Government of India set up the National Mangrove Committee, to advise the Government about mangrove conservation and development. The Government, following the advice of the Committee introduced a scheme for mangrove conservation and protection. The salient features of the scheme are:

1. Identification of selected mangrove areas for conservation

2. Preparation of a management plan
3. Promotion of research
4. Adoption of a multidisciplinary approach involving state governments, universities, research institutions and local organizations.

In 1979, the National Mangrove Committee recommended areas of research and development for mangroves, which include:

1. Nationwide mapping of the mangrove areas, preferably by remote sensing coupled with land surveys, and time series to assess the rate of degradation of the ecosystems.
2. Quantitative surveys of area, climatic regime, rate of growth of forest trees and seasonal variations of environmental parameters.
3. Assessment of suitable sites for reserve forests
4. Conservation programmes
5. Afforestation of degraded mangrove areas
6. Study of management methods, the ecology of mangroves, their flora and fauna, their microbiology and the biochemistry of organic matter and sediments.

On the basis of National mangrove Committee's recommendation, 15 mangrove areas were identified for conservation. The Government of India also provided financial assistance to the states and Union territories for the preparation and implementation of Management Action Plans for the conservation and development of these mangrove ecosystems. Most of these plans are being implemented now.

The Forest Conservation Act, 1980 states that no forest area shall be diverted for any non-forestry purpose without prior approval of the Government of India. This Act is effective in preventing diversion of mangrove forest areas for non-forestry purposes. The Environment (Protection) Act, 1986, and the Notification of Coastal Regulation Zone (CRZ) (1991), following this Act, recognizes the importance of mangroves and classifies them under CRZ-I, which are to be treated as inviolable areas.

1.13 EMPRI's experimental studies on mangrove: Environmental Management and Policy Research Institute (EMPRI) carried out some studies on mangroves. Several locations have been visited covering all the important estuaries and the vegetation studied. Due to the fringing nature of mangroves it is difficult make any quantitative estimates of the mangroves. The data about species was collected locality-wise, submitted to integrate with remote sensing data to ISRO, so as to facilitate a comprehensive information system on Karnataka's mangrove diversity. The latitude and longitude of all the study locations have been collected using the Geographical Positioning System (GPS). This study, being of limited nature, was carried out, as a one time study is a good record for most of the perennial plants, both mangroves and non-mangroves.

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