Mangrove Ecosystems in India and their Conservation

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Introduction

Mangroves are salt-tolerant forest ecosystems found mainly in tropical and sub-tropical inter-tidal regions of the world. They are associations of halophytic trees, shrubs or other plants that have the common trait of growing in shallow and muddy salt water or brackish waters, especially along quiet shorelines and in estuaries. Typically they produce tangled masses of arching roots that are exposed during low tides. Mangroves do not appear on sandy beaches and rocky shores. A muddy substratum of varying depth and consistency is necessary for their growth. Mangrove forests are one of the most productive and biodiverse wetlands on earth. It is found on tropical and subtropical coastlines between 30°S to 38°N in the world and covers about 15.2 million hectares in 124 countries. The total area of mangroves in Indian Ocean region is 84,985 km^2 equivalents to about 47% of the total area of world mangroves (Kathiresan and Rajendran, 2005). Yet, these unique coastal tropical forests are among the most threatened habitats in the world. The world has lost 35% of its mangrove forests over the last twenty years. The rate of loss of mangroves each year tops the loss of the rainforest at 2.1%. At the current rate of destruction, all of the world's mangroves will disappear in 50 years.

The mangroves are sources of highly valued commercial products and fishery resources and also as sites for developing a burgeoning ecotourism (Kathiresan and Bingham, 2001). Growing in the intertidal areas and estuary mouths between land and sea, mangroves provide critical habitat for a diverse marine and terrestrial flora and fauna and protect coastal areas from erosion. As mangrove ecosystem is suitable for brackish water shrimp culture, a large number of aquaculture ponds have been developed in the periphery of Bhitarkanika National Park area of Orissa (Mishra *et al.*, 2008). Mangrove forests have been commercially used for timber extraction along the east coast, especially in Sundarbans. They also serve as a source of firewood and as green fodder especially in the Gulf of Kachchh and Tamil Nadu. Tannin is extracted from the bark of some mangrove plants such as *Rhizophora mucronata*, *Bruguiera gymnorrhiza* and *Ceriops tagal*. The extract is used by the fishermen to dye their fishing nets to increase their durability (Kathiresan and Qasim, 2005). Because of the uniqueness of mangrove ecosystems and the protection they offer against erosion, they are often the object of conservation programs.

Distribution

India covers about 4,445 km^2 area of mangroves (FSI, 2005). East coast of India has larger mangrove areas than the west coast due to availability of nutrient rich river deltas and terrain. West Bengal has the greatest area of mangrove cover in the country, followed by Gujarat and Andaman and Nicobar Islands. About 60% of the mangrove cover is found on the east coast of India, 14% on the west coast and the remaining in the Andaman and Nicobar Islands. Extensive mangrove forests occur in the major river deltas such as Budhabalanga, Subernarekha, Brahmani-Baitarani (Bhitarkanika), Mahanadi and Devi river mouths of Orissa coast extending over 480 km along the Bay of Bengal. The total areas of mangroves in different states are given in Table 1.

Table 1: Mangrove cover in states and UTs in 2005

State/UT	Very dense mangrove (km^2)	Moderately dense mangrove (km^2)	Open mangrove (km^2)	Total (km^2)	Change in mangrove cover w.r.t. 2003 Level (km^2)
Andhra Pradesh	0	15	314	329	0
Goa	0	14	2	16	0
Gujarat	0	195	741	936	0
Karnataka	0	3	0	3	0
Kerala	0	3	5	8	0
Maharashtra	0	58	100	158	0
Orissa	0	156	47	203	0
Tamil Nadu	0	18	17	35	0
West Bengal	892	895	331	2,118	-2
Andaman & Nicobar Islands	255	272	110	637	-21
Daman & Diu	0	0	1	1	0
Pondicherry	0	0	1	1	0
Total	1,147	1,629	1,669	4,445	-3

(Source: FSI, 2005)

The mangrove ecosystems

Indian mangrove ecosystem has a total of 3985 biological species that include 919 flora and 3066 fauna. Mangroves are of much ecological significance as they protect the coasts from solar UV-B radiation, green-house effects by removing CO_2 from the atmosphere, fury of cyclones, floods, wave action and coastal erosion. The root systems of plants keep the substrate firm and contribute to the stability of the coast. The mangrove ecosystem is influenced by rainfall, salinity, substratum and tidal amplitude. Rainfall is the source of freshwater inputs for the mangroves and it influence the distribution and composition of mangrove species. Because of the high rainfall in Andaman and Nicobar Islands, Orissa and West Bengal, mangroves are luxuriant and diverse there.

Indian subcontinent is composed of 72 species of exclusive mangroves and 165 species of associate angiosperms and 676 species of sub-aerial angiosperms. The unique ecosystem found in the intricate mesh of mangrove roots offers a quiet marine region for young organisms. In areas where roots are permanently submerged, the organisms they host include algae, barnacles, oysters, sponges, and bryozoans, which all require a hard surface for anchoring while they filter feed. Shrimps and mud lobsters use the muddy bottom as their home. Mangrove crabs mulch the mangrove leaves, adding nutritients to the mangal muds for other bottom feeders.

Mangroves are the most productive natural ecosystems. Fish and invertebrate species use mangrove habitats in a variety of ways, at different stages of their life cycles and for different lengths of time. The level of mangrove dependency varies depending on the life history of the species, and the proportion of the life history spent in the mangroves (Manson *et al.*, 2005). Its waters are nursery grounds for fish, crustaceans and molluscs and also provide habitat for a wide range of aquatic life, while the land supports a rich and diverse flora and fauna. The primary food source in the mangrove environment is the particulate organic matter or the detritus derived from decomposition of mangrove litter fall. Tannin liberated by the mangrove vegetation hardens egg cases of finfish and shellfish and provide better survival for hatchlings while the wax from mangrove leaves controls predatory aquatic insects. Mangroves are rich in yeast concentration and their enzymatic activities breakdown cellulose and pectin from shells of dead crustaceans and molluscs, produce carbohydrates and proteins, readily available to the juveniles and young fishes and prawns which feed on detritus.

The influence of mangrove ecosystems extends beyond the mangrove forest limits into the coastal waters. The organic detritus produced by the mangroves is exported at high rates into the coastal zone and supports the productivity of these waters. The realization of the increasing rates of mangroves and the inadequacy of the existing management regime has raised awareness of the need to create mangrove reserves in an attempt to conserve this ecosystem including its flora, fauna and other biotic and abiotic components in its natural state. The creation of mangrove reserves is expected to have a positive impact on biodiversity conservation.

Mangroves grow luxuriantly in low-lying sheltered coastal plains where topographic gradients are small and tidal amplitudes are large. Mangroves are highly adapted to the coastal environment with exposed breathing roots, extensive support roots and buttresses, salt excreting leaves, and viviparous water dispersed propagules. These adaptations vary among taxa and with the physicochemical nature of the habitat (Duke, 1992). Mangroves are tolerant of high salt levels and have mechanisms to obtain freshwater despite the strong osmotic potential of the sediments (Ball, 1996). Mangrove roots take up water very slowly, avoiding excess amount of salt intake (Lin and Sternberg, 1993). The mangroves are healthy and diverse where the land is flat. In Pichavaram, south India, changes in topography and tidal flushing have caused large scale degradation of mangroves (Selvam and Ravichandran, 1998). The highly productive and diverse microbial community living in mangrove ecosystems continuously transforms nutrients from dead mangrove vegetation into sources of nitrogen, phosphorous and other nutrients that can be used by the plants and in turn the plant exudates serve as a food source for the microbes (Sahoo and Dhal, 2009).

Soil properties have a major impact on mangrove nutrition and growth. Soil composition and grain size determines porosity of the soil which ultimately influences soil salinity, water content and amount of nutrients contained in the soil. Mangroves tend to grow well in areas where their roots have ample places for attachment and seem to only do well in mud and very fine sand (Cardona and Botero, 1998). High salinity decreases the rate of photosynthesis; so with lower salinity and more light the net photosynthesis per unit leaf area increases and growth rate of the mangrove increases (López-Hoffman *et al.*, 2007). In south east coast of India, high nutrient concentrations and low salinity from monsoons produce rapid growth in the mangroves. Seedlings grow 5 times and produce 4 times as many leaves in the post-monsoon season as they do in the dry season (Kathiresan *et al.*, 1996). Sulfide is a characteristic feature of mangrove sediments that influences mangrove distributions. High sulfide levels can damage mangrove seedlings, causing stomatal closure, reduced gas exchange, reduced growth and high mortality (Youssef and Saenger, 1998). Soil pH affects the distribution of mangrove species because each species has a different tolerance for different pH levels (Wakushima *et al.*, 1994). It has been found that mangroves achieve maximum root growth at an acidic pH of 6 and maximum shoot growth at an alkaline pH of 10. Anything lower than 6 retards mangrove seedling growth and is a cause of mangrove death (Kathiresan and Thangam, 1990). Nutrients such as nitrogen, phosphorus and potassium are important in mangrove growth. Mangroves are known to remove CO_2 from the atmosphere through photosynthesis and are capable of accumulating and storing carbon in the soil in large quantities. Strong sunlight can also reduce mangrove photosynthesis through inhibition of Photosystem II (Cheesman *et al.*, 1991). Temperature induced changes in the relative rates of photosynthesis and respiration, in turn, influence overall growth rates.

Sundarban mangroves have their own adaptive mechanism to withstand high irradiance and extreme salinity. Photosynthetic rate is decreased and transpiration regulated by restricting stomatal conductance beyond certain PAR (Photosynthetically Active Radiation) almost in all the species. The rate of net photosynthesis and stomatal conductance were higher in members of Avicenniaceae than in Rhizophoraceae. In Avicenniaceae, the optimum PAR for maximum photosynthesis ranged between 1340-1685 $\mu mol\ m^{-2}.s^{-1}$, which was also higher than that of Rhizophoraceae (840-1557 $\mu mol.m^{-2}.s^{-1}$). The combined effects of temperature-induced increase in evaporation rate and decrease in photosynthetic capacity enhance the water cost of carbon gain drastically at leaf temperatures above 36°C and the abrupt rise in temperature leads to denaturing photosynthetic enzymes that, in turn, cause rapid reduction in assimilation rate (Nandy and Ghose, 2005).

The Sundarban mangrove ecosystem

Sundarban means beautiful forest and the name is also derived from sundari tree (*Heritiera formes*). The Sundarbans mangrove forest is located between 21°30'–22°30' N and 89°12'–90°18' E, in the Bay of Bengal covering an area of 10,000 km^2 of which 65% fall within the territory of Bangladesh (FAO, 2003). Indian Sundarban has an estimated area of 1,781 km^2 under water while 4,225 sq. km is under reserved forests. Three million people live there and UNESCO has declared this as biosphere area. The mangrove waters support 53 species of pelagic fish belonging to 27 families and 124 species under 49 families of demersal fish (Hussain and Acharya, 1994). Out of an annual total of 120,000 t of hilsa (*Tenualosa ilisha*), nearly 13,000 t comes from the Sundarbans. Hilsa landings from the mangroves has reduced by 38% in recent years in a decade (Islam and Haque, 2004). It has been estimated that 10 cm sea level rise will inundate 15% of the Sundarbans. Subsequently, 25 cm, 45 cm, 60 cm sea level rise will inundate 40%, 75% and 100% of the Sundarbans, respectively (Hoq, 2007). The impacts of mangrove have been reflected in the contribution of artisanal fishery catch that has been in a continuous decline since the 1980s.

Mangroves of Gujarat

Gujarat state, with a coastline of about 1650 km, harbours approximately 936 km^2 of mangroves supporting the second largest block of tidal forests of India. Mangroves in Gujarat are mostly confined to (i) Indus deltaic region, i.e., Kori creek and Sir Creek area, (ii) The Gulf of Kachchh, and (iii) The Gulf of Cambay. Eleven different species of mangroves have been reported from the state of Gujarat so far (Bhatt *et al.*, 2009).

Mangroves of Andaman and Nicobar Islands

The mangrove vegetation of these islands constitutes 9.4% of the land area or 10.85% of the total forest area. Mangroves occurring in these islands are mostly fringing the creeks, backwater and muddy shores. Along the creeks, the width of the shore ranges from 0.5 km to 1 km. At places mangroves found on rocky shores are subjected to tidal action and regular deposits of mud. Luxurient mangroves can be seen in Shoal Bay (South Andaman), Yerrata Jetty in Rangat (Middle Andamans) and in Austrin Creek (Mayabunder). The mangroves of the Bay Islands (Andaman & Nicobar) accounting for 637 km^2 were adversely affected by the December 2004 tsunami. The pre-tsunami data shows about 871.40 ha of mangroves in the Great Nicobar, while the post-tsunami data show only 339.70 ha, leaving 531.70 ha of mangroves to the killer waves (Sridhar *et al.*, 2006). As per available information from various sources 27 tree species, 5 shrubs, 1 climber and 2 species of palms and ferns each belonging to 17 genera are reported to occur in the mangrove ecosystem of these islands. The Lakshdweep Islands are unstable and devoid of mangroves, except in a small area (500 m^2) at Minicoy.

Pichavaram mangroves

Pichavaram mangrove forest (11°20' N lat; 79°47' E long) is located between the Vellar and Coleroon estuaries and covers an area of about 1100 ha, of which 50% is covered by forest, 40% by water-ways and the remaining filled by sand-flats and mud-flats.

Threats to mangroves

Mangroves are among the most threatened ecosystems in the world owing to high demographic pressures and alteration of freshwater and sediment inflows that nourish and maintain their environment. The rapid degradation and removal of mangroves is ascribed to a variety of reasons including fuel and timber extraction, encroachments, brackishwater aquaculture and land use change driven by high population densities. Major changes in mangrove distribution and abundance in coastal regions could result from habitat loss associated with rising sea level (Woodroffe, 1990). Damage to mangroves strongly affects sediment budgets and promotes coastal erosion. In Kerala, embankments are constructed to prevent the entry of seawater, and then for raising coconut trees. This has resulted in destruction of mangroves. The state had 70,000 hectares of mangroves in 1975 and this is reduced to 800 hectares in 2005. Shrimp farming activities in Orissa, Andhra Pradesh and Tamil Nadu caused severe destruction of mangroves. Sundarban mangroves are degrading fast due to huge silt deposition, high salinity, low water table (100 m) and problem of acid sulphate soil, loss of soil fertility, coastal erosion and a steep fall in fishery resources, biodiversity loss and regeneration problems of obligate mangrove plants.

Natural mangrove destruction is caused by cyclones, storms, occasional tsunamis, floods, intensive grazing, and infestation by pests, insects, oysters, and wood borer. Anthropogenic destruction activities include urbanization, agricultural activities (e.g., paddy, coconut, aquaculture, salt pans), industrial activities, constructions of jetties and ports, dumping of waste material and garbage, effluent release (pollution), mining, deforestation, fodder and leasing area for grazing purpose and reduction or increase of the quantum of freshwater by dam constructions or diverting the flows, respectively. Among the pollutants, oil could be the most serious problem, because it covers pneumatophores, suffocating mangroves and resulting in their mortality (Jagtap and Nagle, 2007).

Conservation

People's participation is important for conservation and management of mangrove ecosystem. Ministry of Environment and Forests has set up a National Committee on Mangroves and prepared the management plan which includes (i) afforestation, (ii) regeneration of degraded mangrove areas, (iii) protective measures and (iv) eco-development. Natural and artificial regeneration activities should be initiated in mangrove degraded areas. Natural regeneration involves the natural process of establishment of 'seeds' of mangroves. Artificial regeneration involves planting of seeds or seedlings in areas where there is inadequate availability of planting materials. There is imperative need to formulate proper restoration practices for mangrove plantation in degraded coastal areas. For this, fast growing species such as *Avicennia* and *Sonneratia* are preferable. To achieve successful mangrove plantation programmes, it is vital to develop nursery stocks of high quality species for their efficient performance in the field. Mangroves are largely degraded in Tamil Nadu and Andhra Pradesh due to high salinity of dry soil as a result of lack of regular tidal flushing. To overcome this situation Canal-Bank Planting Technique was suggested by MSSRF (MSSRF, 2002). In this technique, canals are formed so that high saline soil gets regular tidal inundation, leaches out salts and becomes suitable for regeneration of mangrove vegetation. This technique involves formation of the feeder canal; 3 m-top, 1 m bottom and 1 m deep; and the distribution canals of 2x0.75x0.75 m dimension in the mud flats and planting propagules directly in the inter-tidal zone of the canals. Along the banks of the canals, planting is made. Mangrove restoration activities involves – fencing, removal of weeds, transportation of saplings, digging of channels, collection of propagules locally, planting, protection and maintenance. As Gujarat and West Bengal fall under the high tidal amplitude areas, it is suggested that the existing planting technique of direct seed sowing and planting seedlings in the mud flats should be continued. In a nutshell, wherever tidal amplitude is low, the preference for restoration should be the canal bank planting technique with fish bone design; and, wherever tidal amplitude is high, the technology adopted should be seedling planting and direct seed sowing in the mud flats.

Conclusion

Mangroves are degrading fast due to urbanization, pollution and industrial development. Mangrove management should be an important component of the coastal zone management of the country. Public awareness need to be raised regarding the value of mangroves.

Community and industrial partnership are required in protecting the mangroves. Conservation of important mangrove species need to be initiated under all India level coordinated projects. Regular monitoring using remote sensing and ground truth data is needed to study the changes in mangrove cover. Cooperation among international mangrove institutions should be enhanced to exchange ideas and experience in the field of mangrove ecosystem and its management.

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