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12 Studies on the mangrove ecosystem

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ABSTRACT

Mangrove ecosystem is one of the most specialised and productive coastal habitats in the world. Due to human interference in many ways, most of the mangrove forests are on the verge of destruction and disappearance. The main causes for the degradation of Indian mangroves are land reclamation, pollution and overexploitation of the resources. A proper understanding of this specialised ecosystem and careful implementation of the conservation measures would alone save the ecosystem from further destruction and extinction. The present account deals with the ecological aspects of the mangrove habitats covering their extent, distribution, zonation, biological assemblage, hydrography and productivity, and giving importance to their role, man-made impacts and conservation aspects with emphasis on the approaches for the sustainable use of this ecosystem to the mankind with special reference to the mangroves of India.

Introduction

Mangrove ecosystem is one of the most productive coastal habitats in the world. The word 'mangrove' is used to refer to the plants and also to the forest community which occur along the tropical inter-tidal areas. Mangroves are also regarded as the 'tropical tidal wet lands' distributed generally between 20° N and 20° S latitudes and they are tropical analogues of the temperate salt marshes. To avoid confusion, Macnae (1968) proposed 'mangal' as a term to refer to the forest community and 'mangroves' to the plant species. They are characterised by the typical vegetation found along the border of the sea, lagoons, riverine estuaries and backwaters to the limit of salt water penetration, occupying the inter-tidal zone close to but above the local mean sea level. During the past few decades, due to human interference in several ways, most of the mangrove forests are on the verge of disappearance. Of

late, the Government, Scientific Institutes and Universities are paying increasing attention to restore the mangrove ecosystems realising their importance, role on national economy and ecological significance. A proper understanding of this specialised ecosystem and careful implementation of the conservation measures would alone save this ecosystem from destruction and extinction. This paper presents a comprehensive account of the extent of mangroves, their distribution, zonation, biological assemblage of the ecosystem, hydrography, organic production, human impacts and the important conservation aspects of the mangrove ecosystems in India.

The extent of mangroves

The mangroves are distributed on the three fourths of the tropical coastline (Chapman , 1975) and these forests are estimated to cover an area of 1,00,000 sq. km. over the world (Deshmukh and Balaji, 1994). In the early sixties, the mangrove areas of India were estimated as about 6,82,000 ha (1.sq.km. = 100 ha) including those of Andaman-Nicobar islands, of which Sundarbans alone contributed nearly 4,19,000 ha (Sidhu, 1963). In a revised report during eighties, the same was estimated as about 3,56,000 ha (CMFRI newsletter, 1984). However, according to the Status Report of the Government of India (1987), the total area of mangroves in India has been assessed as 6,740 sq. km. which constitutes nearly 7% of the world mangroves; while in the nineties, the latest Remote Sensing Data (Nayak,1993) shows an extent of about 4,500 sq. km. only (Table - 1).

Table - 1: Extent of mangroves in India (sq.km.)

State	Status Report (1987)	Remote-Sensing Data (1993)
West Bengal	4,200	1,619
Andaman-Nicobar	1,190	770
Orissa	150	187
Andhra Pradesh	200	480
Tamil Nadu	150	90
Gujarat	260	1,166
Maharashtra	330	138
Goa	200	5
Karnataka	60	19
Kerala	Sparse	Sparse
Total	6,740	4,474

Distribution

The global distribution and abundance of mangroves indicate that they are generally more along the tropical coastline of the east coast than on the west coast of the continents. In India also, the east coast contributes nearly 70%, west coast 12% and the bay islands (Andaman-Nicobar) accounts for about 18% of the mangroves (Status Report, 1987).

The Sundarbans of India and Bangladesh put together form the largest single block of mangroves of the world (Blasco, 1975). Next in importance along the east coast of India are the river mouth regions of Mahanadhi, Godavari, Krishna and Cauvery. Along the west coast, mangrove formations occur around the Gulf of Kutch, Gulf of Cambay, along the estuarine border of Mandovi-Zuari, Nethravathi, Dharmadam and the Cochin backwaters (CMFRI newsletter, 1984).

Zonation

Diversity in the formation and zonation of mangrove forests can be witnessed along the latitudinal and longitudinal gradients. Across the latitudinal gradient, air temperature and across the longitudinal gradient, water and soil fertility appear to be the important factors in determining the distribution, density and growth of mangrove community. Macnae (1968) classified the mangroves under two categories, viz. (a) the fringing mangroves of estuaries and (b) the mangrove swamps of backwater area. Another classification divides the mangroves as the 'tidal mangroves' (submerged at high tide of spring tides) and 'swampy mangroves' (submerged at every high tide). The 'tidal mangroves' are found where estuarine environment prevails and their formation is more along the border of the net-work of canals and creeks; while the 'swampy mangroves' prefer the mudflats with fine grained sediments predominently of silt and clay particles.

Three schemes have been postulated to describe the zonation of mangroves (Macnae, 1968) of which two are based on the physical factors of the environment and the other is based on the dominant group.

(1) Based on the frequency of tidal inundation as shore land gets flooded:

(a) at all high tides

(b) by medium or normal high tides

(c) by spring tides only, and

(d) by other exceptional tides alone.

(2) On the basis of salinity gradient:

(a) Brackishwater to saltwater zone (10-30 ppt); and

(b) Freshwater to brackishwater zone (trace to 10 ppt).

(3) On the basis of dominant group available in the area : such as

(a) *Rhizophora* zone,

(b) *Avicennia* zone, (c) *Ceriops* zone etc.

Rainfall or freshwater supply, tides, temperature, topography, currents, waves and winds are said to have influence on the mangrove formation, zonation and distribution. It is noteworthy that today, in Kerala, there is no dense mangrove area in spite of its generally very heavy rainfall as compared to the other states of west and southeast coasts of India. Although temperature influences the development and survival of the mangroves in the early stages; salinity determines the distribution and zonation; tidal amplitude determines the landward extention of mangroves; wind is important in regulating the seasonality of litterfall; waves and currents are responsible for erosion and in the transportation of seed and seedlings; and human interferences and natural catastrophies have significant role on the destruction of mangroves at one stage or other. it is the cumulative effect of these factors that determines the formation, zonation, distribution and extent of the mangroves.

The environment

Mangrove vegetation:

There are totally 17 genera and 69 species of mangrove plants (Duke, 1992) of which, there are 48 species recorded in India. The mangrove swamps and forests are more diverse and luxurient in the Indopacific region comprising of about 60 species, while those of Atlantic coast are less diverse with 10 species only.

On the basis of the height of the vegetation, three categories of forest stratification can be observed in the normal mangrove ecosystem: (a) The larger trunk with wide spreading crown is found in species of *Sonneratia* and *Avicennia* and less spreading crown found in species of *Bruguiera* and *Rhizophora* which constitute the top canopy of the forest; (b) The second category is contributed by shrubs and small trees represented by species of *Aegeceros, Excoecaria and Ceriops*; (c) The third one is occupied by small shrubs and ferns such as species of *Acanthus, Acrostichum etc.* These are the chief primary producers and their contribution in organic production is 80-90% in the ecosystem.

Other flora :

The other sources of primary production in the mangrove ecosystem are the algal colonies associated with the mangrove root surface and the moist intertidal flats, followed by the phytoplankton communities in the associated bays and lagoons. The organic production from phytoplankton ranges from 1 to 6% of the total organic production in the mangrove ecosystem. The benthic algae of the mud surface and the mangrove root surface are represented by the green filamentous species of *Enteromorpha, Monostroma,* and *Rhizoclonium* (Gopinathan and Selvaraj, 1996) and their contribution is considerable in this ecosystem. The microbial population in the bottom sediments is about seven fold greater than that of the marine littoral zone.

Faunal assemblage:

The mangrove associated fauna belonging to the terrestrial, estuarine and marine habitats constitutes representatives of almost all invertebrate phyla and certain Chordates like fishes, crocodiles, birds, monkeys and some other mammals. Some of the common and important crustaceans are the penaeid prawns of the genera *Penaeus* and *Metapenaeus*, certain nonpenaeid prawns, and crabs like *Scylla serrata*. The common molluscs are species of *Crassostrea, Meretrix, Telescopium* and *Cerethedium*; and of fishes are species of *Mugil, Liza, Lates, Polynemus, Lutjanus, Etroplus, Ilisha, Gerres* and some gobiids

The Central Marine Fisheries Research Institute conducted series of surveys to the important mangrove areas along the Orissa coast, Andaman - Nicobar islands, Kakinada (Godavari mangroves), Killai (Pichavaram) and

Tuticorin along the east coast and Gulf of Kutch, Dharmadam and the Cochin backwaters along the west coast of India to understand the ecological and faunal characteristics of the mangrove ecosystems with special reference to the finfish and shellfish resources (CMFRI newsletter, 1984). As an example, in the Godavari mangrove ecosystem around Kakinada, the prawns, fishes, molluscs and crabs contributed on average 82, 9, 8.5 and 0.5% respectively in their numerical composition. The influence of the prawn seed and juvenile resources on the artisanal fishery of the neighbouring sea around Kakinada has been studied with special reference to Godavari mangrove ecosystem (Selvaraj, 1994). This bay is having good bivalve resources of *Anadara granosa*, *Placenta placenta* and *Meretrix meretrix* (Narasimham *et al.*, 1984). The root system of mangroves along the border of the estuaries provides shelter for variety of crustaceans and molluscs; and the shallow net work of creek and canals in the mangrove ecosystem provides shelter for the seed and juveniles of important finfish and shellfish resources.

Hydrographic features:

In the annual cycle, the air temperature of most of the mangrove habitats normally ranges from 20-35°C while the surface soil temperature ranges from 25-32°C and surface water temperature 23-33°C; salinity fluctuates much in space, time and with tide, ranging from 0.1 to 33 ppt in landward and creek waters; while in the bay, it ranges from 25-35 ppt; and the soil salinity between 12 and 36 ppt. Hypersalinity is detrimental to the survival of mangroves. The pH of the water normally fluctuates between 6.5 and 8.0; and the dissolved oxygen in water is normally low ranging from 2.0 to 4.0 ml/l and the values may increase towards upstream and seaside. Among the nutrients, nitrate concentration is usually 4 times greater than in sea water, inorganic phosphate 20 times greater, silicate concentration 10 times greater, and of the suspended particles in the mangrove associated waters is 20 times higher than in the sea water.

Primary production:

Mangrove areas are among the most productive ecosystems of the world. Their rate of production of organic matter is on average 20g/m^2/d. (Kathiresan, 1995); and the annual litterfall normally ranges from 10,000 to 14,000 kg. dry weight per hectare. It has been estimated that the annual mangrove leaf litter production in the Pichavaram mangrove ecosystem is about 6,310 tonnes

(7.5 tonnes/ha/year) of which 3,786 tonnes /yr is transported to the adjoining Bay of Bengal (Muniyandi, 1985; Krishnamurthy, 1985).

Regarding the primary productivity of the mangrove associated waters Gopinathan and Rajagopalan (1983) have reviewed the productivity potential of the Andaman-Nicobar mangrove zones. According to Nair and Gopinathan (1983), the values ranged from 0.2 to 0.8 g. C/m^3/day in the Northern Andamans, slightly higher values of 0.5 to 1.0 g.C/ m^3/day in the shallow mud flats and mangrove zone of Car-Nicobar and very high production rate of 2.0 to 3.6 g.C/m^3/day recorded in and around the mangroves of Port Blair.

As per the investigations made by the author, the seasonal average primary productivity values in the waters of Godavari mangrove ecosystem around Kakinada (Andhra Pradesh) ranged from 0.25 to 0.75 g. C/m^3/d with the mean value of less than 0.5 g.C./m^3/d although the highest value at some area reached upto 2.5 g.C./m^3/d; In the Pichavaram mangrove waters (Tamil Nadu), the seasonal averages ranged from 0.36 to 3.3 g.C/m^3/d with the mean value of 1.67 g.C/m^3/d while the highest value reached upto 5.3 g.C./m^3/d; And in the Dharmadam estuarine waters associated to the mangroves (Kerala State), the seasonal average values ranged from 0.24 to 1.14 g.C/m^3/d with the mean production rate of 0.63 g.C./m^3/d and the highest value reaching upto 2.07 g.C/m^3/d in summer months. In the Cochin backwaters, these values ranged from 0.37 to 1.37 g.C./m^3/d with an annual average production rate of 0.66 g.C./m^3/d while the highest values reached upto 2.15 g.C./ m^3/d. (Rajagopalan *et al.*, 1986).

Organic cycling:

The mangrove ecosystem, with its variety of habitats provides living space for more than two thousand species of flora and fauna of resident, semiresident and migratory modes of life. This estuarine ecosystem is not a closed system and it has free connection with the open sea on one side and with the river on the other side with the exchange of organic and inorganic matter at every tide and by the flood flow. Organic matter is stored in three forms, viz, living tissue, detritus and dissolved form within the mangrove ecosystem and the organic cycling is influenced by two fators namely (a) the rate of conversion of living tissue into detritus (by death and decay) and (b) the rate of conversion of detritus into dissolved organic and inorganic forms (by microbial action); of which the former is faster than the latter (Fig.1) resulting in accumulation of detritus, chiefly

contributed by the mangrove litter fall (>80%). Krishnamurthy (1985) has reported that on average 60% of the annual mangrove litter production from the Pichavaram mangrove ecosystem is transported to the neighbouring sea.

The detritus plays an important role in the food-web of the mangrove ecosystem (Fig.2). The predators feed on the detrital feeders and form important food source for both aquatic and terrestrial wild life. An additional source of nutrition is in the form of dissolved organic compounds in water. It has been estimated that an average production of 100 mg. C per litre is derived from the mangrove associated waters, 10 mg. C per litre through the rivers and 1 mg C per litre from the neighbouring sea.

The role of bacteria is important in the synthesis of organic matter by dark fixation and in the biochemical decomposition and other oxidation and reduction processes involved in the ecosystem. The bacteria convert the organic matter into inorganic nutrients and enrich the soils and aquatic environment and these nutrients are utilised by the macro and micro primary

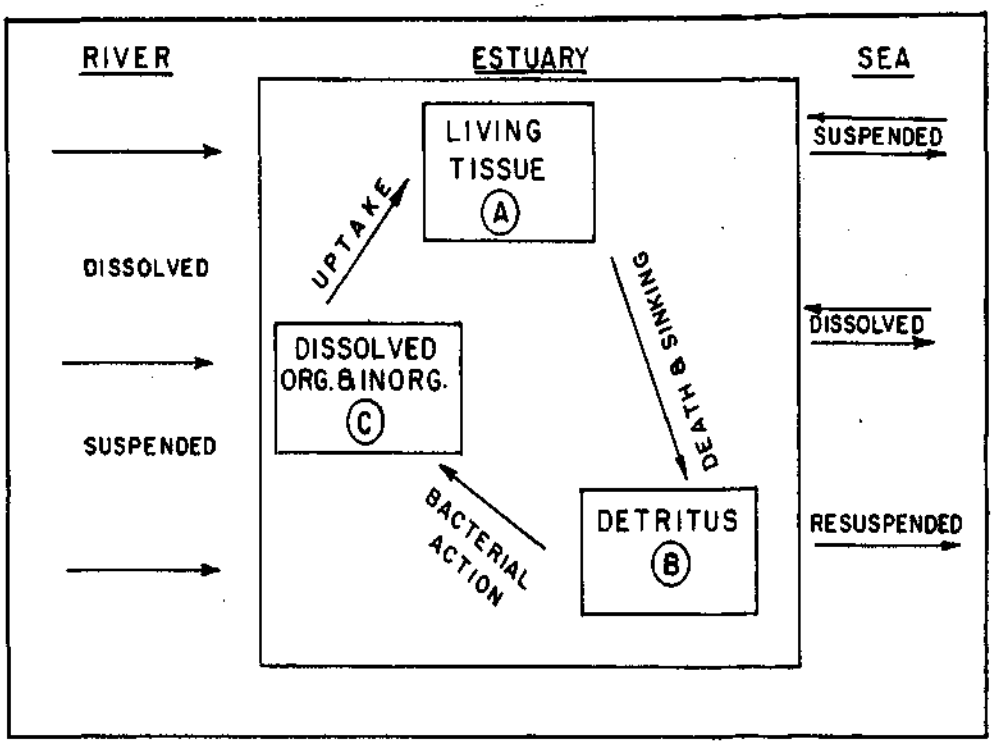

Fig.1. Chief organic reservoirs involved in the organic cycle of mangrove ecosystem

producers of the ecosystem (Fig. 3). The roots of the mangrove Plants absorb the nutrients and they are translocated to all parts of the mangroves for their growth and multiplication. The dynamics of the biogeochemical cycles associated with the organic production and recycling in the mangrove environment have not been adequately understood.

Very few studies have been made with respect to plant-animal interactions in this ecosystem. It has been estimated that the insects consume about 20-25% of the available mangrove leaf tissues (Deshmukh and Balaji, 1994); and Qasim *et al.* (1969) have estimated that the average annual consumption of primary (phytoplankton) production by zooplankton herbivores is about 25%. More works on these aspects to fill the lacunae in the studies of organic cycling in the mangrove ecosystem are desirable.

The role of mangroves

Mangroves form the natural wealth of the country. The mangrove forests, with their anchoring and radial root system help in consolidating and stabilizing the loose muddy soils and control soil erosion along the coast to a

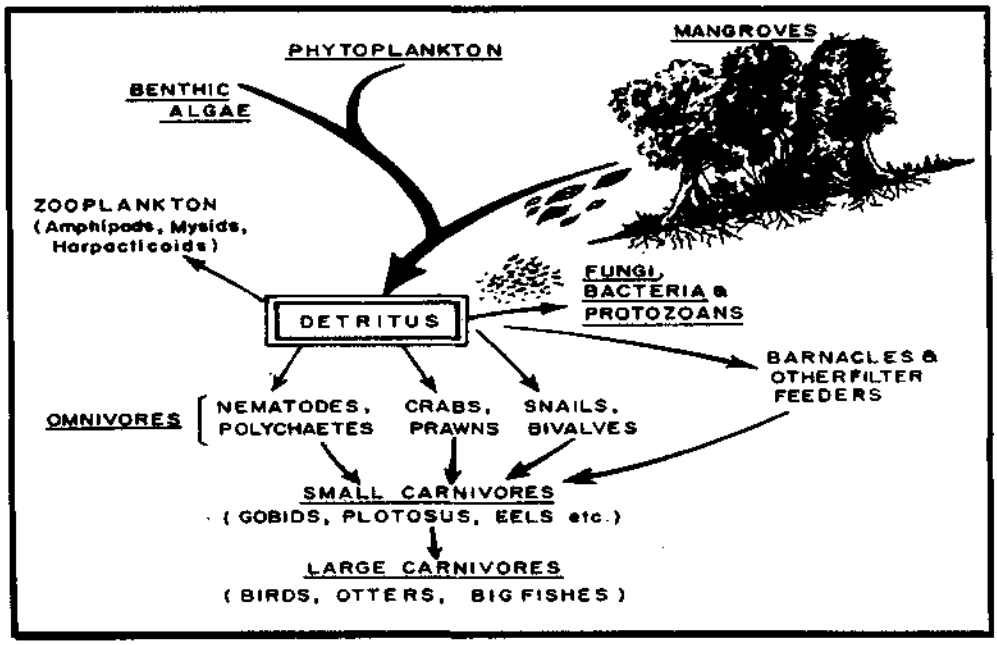

Fig.2. Detritus Food-web in mangrove ecosystem

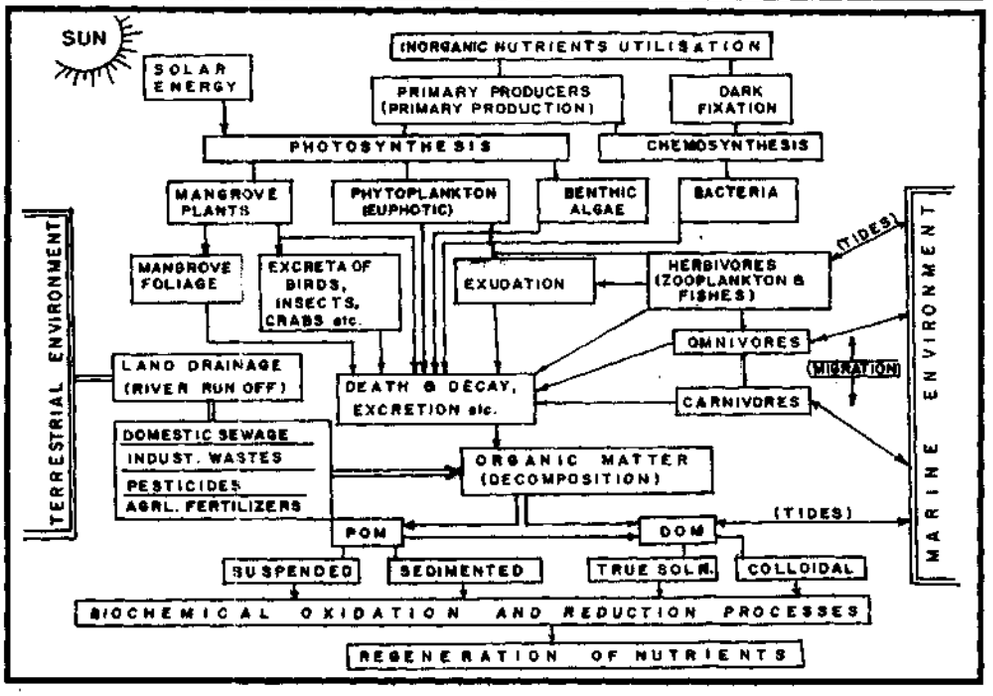

Fig.3. Pathways of organic cycle in the mangrove ecosystem

greater extent. The parts and products of mangroves provide other resources to mankind (Gopinathan and Selvaraj, 1996).

The mangroves provide areas of high biological productivity. The major source of organic production is derived from the decomposition of mangrove litterfall. The death and decay of the flora and fauna of this ecosystem increase the organic production in the form of particulate organic matter (detritus) and dissolved organic compounds which provide the source of nourishment to a variety of detritus feeding animals; while the other animals and birds inhabiting in the ecosystem are indirectly associated to the detrital food-web (Fig. 2).

The mangrove associated bays and backwaters have very good potential of culture and capture fishery activities. In the global level, small scale fisheries in the mangrove waters produce nearly one million tonnes of crabs, shrimps, molluscs and finfishes annually; and the mangroves provide direct employment to about 0.5 million fisherfolk (FAO, 1988). According to Krishnamurthy (1983), the annual yield from the mangrove-cum-estuarine dependent fisheries

of India is about 30,000 tonnes of shellfishes, of which almost 50% is contributed by prawns alone (Palomares, 1985). Parulekar (1985) has dealt with the aquaculture potential of the Indian mangrove ecosystems.

This ecosystem serves as the feeding and breeding ground for several coastal marine and estuarine species and as a nursery area for their seed and juveniles also, thus providing good collection centres for economically important finfish and shellfish seed resources.

The estuaries and backwaters fringed by the mangroves have long been used for rearing and fattening of bivalves, crabs, prawns and finfishes. Edible species of oysters and clams are potential cultivable groups in the mangrove ecosystem. The culture of the mud crab *Scylla serrata* is found profitable in philippines, Malaysia, Thailand and Thaivan using wild juveniles. Among prawns, *P.monodon*, *P. indicus*, *P.merguensis* and *M. monoceros* are used in farming practices in southeast Asian countries. Among fishes, milk fish, mullet, pearl spot, cat fish and predatory fishes like groupers and seabass are found suitable for culture in this ecosystem. Recently, experiments on seaweed culture of *Gracilaria*, *Caulerpa* and *Ulva* have proved good farming potential in the shallow mangrove areas, where the water is not turbid.

Besides these, the mangrove ecosystems, with the variety of habitats offer a range of recreational activities such as tourism, boating, hunting, bird watching, wild life observations, education trips, specimen collection, photography, etc. and also serve as sanctuaries of birds and other endangered species of wild life.

Human impact on mangroves

Increasing human pressure for domestic needs and development of industries have virtually destroyed large areas of virgin mangroves in the past few decades. Overexploitation by the traditional users, conversion of mangroves to agriculture purposes, salt pans, urban development, tourism development, construction of harbours and for garbage, sewage and effluent disposal cause serious damage to this habitat. The construction of barrages and bunds to promote irrigation and agriculture and reclamation processes have brought imbalance in the ecosystem which disturb even the bird and wild life sanctuaries of endangered species associated with this ecosystem. Nowadays the mangrove environment is getting polluted with effluents and

other contaminants from the factories and industrial wastes. Heavy metals pose serious problem due to their environmental persistence and toxicity to aquatic organisms. Sewage discharge with high BOD, excessive release of pesticides and fertilizers in water from agriculture and aquaculture practices have threatened the mangrove ecosystems, while some mangrove ecosystems are in the verge of destruction and extinction, which need immediate attention.

Conservation and management

The main causes for the degradation of Indian mangroves are land reclamation, pollution and overexploitation of the resources. For a sustained improvement and utilisation of mangrove resources and to enhance biological diversity, as one may think, conservation and preservation of the existing mangrove resources could be the first step. But, there are basically three options left for the management of mangroves. The first option is 'preservation' of the ecosystem in the natural state; and the second is 'utilisation' of the system to extract various goods and services on a sustainable basis. The third option is the 'conversion' of the natural ecosystem for other uses such as agriculture, aquaculture, housing and other urban developments. It is important here to recognise that all these three options have related costs and benefits; and economic analysis has a role to play in this process to minimise the costs and maximise the benefits.

The aspects on conservation and management of mangroves with action plan and priorities have been dealt in detail by Gopinathan and Selvaraj (1996). However, sustainable use should be the theme of prime importance in the approaches to overcome the social, economic and ecological impacts. Some of the important aspects which need immediate attention to evolve frame work for proper conservation and management are:

(a) Exclusive banning of the most affected mangrove area from further exploitation with strict protective measures from the Government side;

(b) To declare potential mangrove areas as 'Reserve' or 'National park' and 'Sanctuaries';

(c) Reforestation of denuded mangrove areas through development of mangrove nurseries; and

(d) To locate and declare certain mangrove areas for tourism, certain other areas for capture fishery activities, certain areas for aquaculture and

seed collection purposes and selected areas for urban development in achieving sustainable yield and profits from the mangrove ecosystem.

Only a rational management can provide a long lasting solution which can be achieved by creating public awareness and by combining the scientific appreciation and suggestions of the stress effects with the socio-economic needs of the mangrove dependent population.

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