Mangroves
The Most Fragile Forest Ecosystem

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Mangroves, an exclusive group of plants with remarkable ecological importance, inhabit mostly the zones washed by the back and forth movement of tides. They are disappearing rapidly from their natural habitat due to various reasons. Mangroves create a unique ecological environment that is composed of rich assemblages of species. Economic importance of mangroves is also noteworthy.

Mangroves live a hard amphibious life in the shoreline where the rivers or rain streams associate with the ocean water. They face submersion every day for twelve hours under high tide. They anchor to soil with their profusely-branched roots. Water remains stagnant within these root nettings. The silt brought by water also settles beneath mangrove trees. The silting process ultimately results in a higher landmass. Plants other than mangroves then occupy these elevated areas. Mangroves extend towards the sea and gradually take hold of the submerged lands. They occur mostly in the tropical and subtropical regions of the world.

Mangrove Forests

The origin of the term ‘mangrove’ is not known with certainty. Perhaps it is a combination of the Portuguese word ‘mangue’ and the English word ‘grove’ [1].

Mangrove forests include taxonomically diverse plants exhibiting common adaptive features. These forests constitute two main types of plant associations. Those plants showing endurance to salinity are considered as true mangroves. Also certain mesophytic plants (upland community) occurring near the coast form mangrove associates. Some mangrove plants occur close to shore, fringing islands and sheltered bays. Others are found farther

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Mangrove forests represent a specialized littoral ecosystem that is extremely fragile.

inland, in estuaries influenced by tidal submergence. Their distribution, association and zonation from deep water to upland communities are influenced by some definite parameters like climate (temperature and rainfall), salinity and tidal range, substrate, underlying geology and wave energy.

True mangrove plants grow and complete their life cycles in the saline swamp habitats. So they fall under the ecological community named *helophilous halophytes* [2]. According to the enhanced tolerance against salinities, true mangroves are further subdivided into three groups: high salt-tolerant, moderately salt-tolerant and less salt-tolerant species.

Mangroves represent highly specialized littoral forest ecosystem swarmed with numerous animals ranging from invertebrates to higher mammals. This community of plants and animals in the tidal swamp habitat exchanges matter and energy with adjacent terrestrial and marine ecosystems. However, mangroves are least understood among the several ecosystems. They are extremely fragile and can suddenly disappear, thus disrupting the coastline.

Mangrove ecosystem is beset with excessive litter. Leaves and other senescent parts of mangrove plants contain large amount of tough, comparatively indigestible cellulose, lignin and wax, and are therefore unsuitable for herbivores. Many anaerobic bacteria such as *Methanobacterium*, *Methanococcus*, *Methanospirillum* and free-living nitrogen-fixing bacteria such as *Azotobacter*, *Desulfovibrio* as well as different microfauna and fungi degrade cellulose, lignin, resin, and carotenoids of leaf litter. They transform litter into proteins and carbohydrate-enriched detritus particles ready for digestion by faunal groups [3]. These detrivores (animals eating detritus) are small animals (*Figure 1*) comprising of amphipods, bivalves, crabs, copepods, grass shrimps, insect larvae, mysids, nematodes, etc., They derive nutrition by eating and re-eating (by means of coprophagy) the detritus. Some minnows and small game fishes eat these animals. Thus the detritus food chain continues. It regulates the

*Figure 1. Crabs acquire an important position as detrivores in each mangrove ecosystem.*
biogeochemical cycling of nutrients on one hand and ensures highest productivity on the other.

**Stress Structures**

Mangrove vegetation faces a peculiar environment that prevails in the tidal zones. They usually grow on yellowish brown to grey soil comprising of sandy to silty clay with rich humus content. This soil is oxygen deficient and with less nitrogen content. In these swamps, the soil is waterlogged throughout the year. Although the soil contains adequate water, yet plants cannot avail this water because of its high salt concentration, (up to 90 per cent) mostly sodium chloride, magnesium chloride and magnesium sulphate. This is a physically wet but **physiologically dry** type of soil. Soil pH ranges from 5.4 to 7.8, i.e., more or less acidic.

**Ways of Taming the Odds**

Proper stress management is the only survival strategy of mangrove plants facing extreme environmental conditions. To cope with the situation, they have adapted themselves in various unprecedented ways [4]. By their subterranean tap root system, mangroves can grip the soil and try to collect capillary water. In some cases, corky stilt roots (*Figure 2*) develop that support the plant in tidal currents. Other type of roots are profusely branched, negatively geotropic and usually come out of the mud surface to access atmospheric oxygen. These roots are called pneumato-

*Figure 2. Supporting stilt roots of young (a) Bruguiera and (b) Rhizophora plants. Such roots of mangrove even resist tsunami.*
Exposed surface of pneumatophores is provided with numerous pneumathodes (or breathing pores) for gaseous exchange. Pneumatophores contain large air spaces and aerenchyma tissue. This tissue acts as a reservoir of air during the submersion of roots in high tide. Some mangroves spread out cable-like shallow holding roots with special knee-like appearance.

Trunks of the arboreal (predominantly woody) species are stout, covered with thick bark and usually develop succulence for water storage. Shrubby or buttonwood mangroves are also with comparatively thick bark. The wood and bark of a mangrove tree contain a higher amount of tannins to overcome the surrounding salinity. Leaves are small sized, thick, glazy, leathery and usually succulent. Besides, veritable salt glands (Figure 4) in the leaves are capable of excreting the salt that has penetrated into the tissues. In some genera (such as Aegiceras, Sonneratia, etc.,) leaves are provided with well developed aqueous tissues to retain water. Flowering (Figure 5) occurs in different seasons of the year, depending on the species. However, most of the mangroves bear insect pollinated flowers. Fruits and seeds are generally light in weight. Fruit walls are spongy having a number of air chambers to float on water.

Most mangroves are viviparous. Their seeds germinate within the fruit while it is still on the tree. This adaptation helps the propagules (a massive club-shaped hypocotyl and terminal radicle pointing
downward emerge out of the fruit) that generally get dispersed by the sea currents. They quickly get fixed in the silt along the coastline (Figure 6). However, propagules can survive long periods in the sea. Soon the propagule begins to float vertically and sprouts its first leaf and roots. When it touches the soil, it grows more roots, and produces more leaves. Young seedlings can survive being completely submerged until they are big enough to grow aerial roots in about 1 or 2 years [2].

### Distribution and Indian Perspective

Mangroves occur in almost all the continents of the world except Europe and Antarctica. In Asia mangroves grow in Bangladesh, India, Indonesia, Pakistan and Philippines. They are associated with large tropical deltas of the Amazon, Ganges, Mekong, Niger and Orinoco rivers. Virtually all mangroves can be found at low latitudes, where the environment is warm and humid.

There are three major types of coastal settings on which mangroves in India survive. These are deltaic, backwater-estuarine and insular categories. The deltaic mangroves occur on the deltas made by mighty rivers such as Ganges, Brahmaputra, Mahanadi, Krishna, Godavari and Cauvery along the east coast. The backwater-estuarine type of mangroves that exist in the west coast are characterized by typical funnel-shaped estuaries of rivers Indus, Narmada, Tapti (with delta formation almost absent) or backwaters, creeks, and neritic inlets. The insular mangroves are present in the Bay Islands such as Andaman and Nicobar Islands, where many tidal estuaries, small rivers, neritic islets, and lagoons support a mangrove flora [5].

India has about 4461 square km area under mangrove vegetation. About 60 per cent of this forest is found along the east coast (Bay of Bengal), 25 per cent occurs on the west coast (Arabian Sea) and 15 per cent is found on the Bay Islands (Andaman and Nicobar Islands) [6]. The mangroves are widespread on the east coast of the world.
India due to the nutrient-rich alluvial soil formed by various rivers and a perennial supply of fresh water along the deltaic coast. Deltas with alluvial deposits are almost absent on the west coast. Their place is taken by the funnel-shaped estuaries or backwaters and creeks. Moreover, the east coast has a smooth and gradual slope that provides larger area for colonization by mangroves, whereas the west coast has a steep and vertical slope [5]. In our country mangrove forests are found in nine States and three Union Territories.

Sunderban is the largest mangrove forest (Figure 7) in the world. The region is covered solely by quaternary sediments carried and deposited by the rivers Ganges, Matla and Bidyadhari. The forest is shared by both India and Bangladesh. The total area of the Sunderban landmass is about 10,200 square km [7]. Mangrove vegetation of Indian Sunderban comprises an area of 2120 square km, the next largest being in Kutch with an area of 900 square km, followed by Andaman and Nicobar Islands with an area of 671 square km [6]. The Sunderban enjoys the distinction of being the first mangrove forest to be declared as the Natural World Heritage site for its extraordinary ecosystems.

**Indian Mangrove Biota**

Indian mangrove ecosystems constitute a large number of floral and faunal wealth. Over 1600 plants and 3700 animal species
have been identified from these ecosystems. Floral elements such as true mangroves, associated plant species, sea grasses, sea weeds, algae, phytoplanktons, lichens, fungi, actinomycetes and bacteria are present with high specific as well as genetic diversities. Out of a total 101 species of true mangrove plants (see also Box 1) recorded, 71 are reported to be present in India [2]. A large array of mangrove plants ranging from high salt-tolerant (concentration above 30 per cent) species like *Avicennia alba, A. marina, A. officinalis, Bruguiera gymnorrhiza, B. parviflora, Ceriops*

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
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<tbody>
<tr>
<td>Red Mangrove</td>
<td><em>Rhizophora apiculata, R. mangle, R. mucronata</em></td>
</tr>
<tr>
<td>Orange Mangrove</td>
<td><em>Bruguiera cylindrica, B. gymnorrhiza, B. parviflora</em></td>
</tr>
<tr>
<td>Black Mangrove</td>
<td><em>Avicennia alba, A. germinans, A. marina, A. officinalis</em></td>
</tr>
<tr>
<td>White Mangrove</td>
<td><em>Laguncularia racemosa</em></td>
</tr>
<tr>
<td>Spur Mangrove</td>
<td><em>Ceriops decandra, C. roxburghiana, C. tagal</em></td>
</tr>
<tr>
<td>River Mangrove</td>
<td><em>Aegiceras corniculatum</em></td>
</tr>
<tr>
<td>Buttonwood Mangrove</td>
<td><em>Conocarpus erectus</em></td>
</tr>
<tr>
<td>Mangrove Apple</td>
<td><em>Sonneratia alba, S. apetala, S. caseolaris</em></td>
</tr>
<tr>
<td>Shore Purslane</td>
<td><em>Acanthus ilicifolius</em></td>
</tr>
<tr>
<td>Sundari</td>
<td><em>Heritiera fomes, H. minor</em></td>
</tr>
<tr>
<td>Water Coconut / Golpatta</td>
<td><em>Nypa fruticans</em></td>
</tr>
<tr>
<td>Sea Date / Khadi Khazur</td>
<td><em>Phoenix paludosa</em></td>
</tr>
</tbody>
</table>

*Box 1. Common Names of Some Mangrove Plants*

*Figure A. Sundari (Heritiera minor) tree is now a rare sight in Sunderban.*

*Figure B. Keora or Mangrove Apple (Sonneratia caseolaris) trees in the Sunderban estuary.*
Mangrove forests provide ideal habitats for a host of animal species. decandra, C. roxburghiana, C. tagal, Kandelia candel, K. rhedii, Rhizophora apiculata, R. mucronata, etc.; to moderately salt-tolerant (average concentration 20–25 per cent) species like Aegiceras corniculatum, Excoecaria agallocha, Lumnitzera racemosa, Sonneratia acida, S. apetala and to some less salt-tolerant (concentration below 15 per cent) species such as Heritiera fomes, H. minor, Nypa fruticans, Phoenix paludosa, Sonneratia ovata, etc., support these ecosystems[2].

The faunal components in mangrove ecosystems comprise of terrestrial, estuarine or marine groups. They are adapted to the stressful situation of widely fluctuating environmental parameters [3]. The majority of mangrove fauna is composed of invertebrates (see also Box 2) including sessile forms (porifers and cnidarians), wandering forms (arachnids, crustaceans and insects), burrowing forms (polychaetes, bryozoans, brachyuran crabs, wood boring moluscs and burrowing bivalves) and errant epi-faunal forms (barnacles, molluscs and oysters). They are supported by a large number of meio- and microfauna.

Mangroves are nursery grounds for many commercially important fish species such as Ambassis commersoni, A. gymnocephalus, Anguilla bengalensis, A. bicolor, Dasyatis uarnak, Elops ma-chnata, Liza macrolepis, Secutor ruconius, Velamugil

Box 2. Some Common and Economically Important Invertebrate Fauna of Indian Mangrove Forests

<table>
<thead>
<tr>
<th>Name of the groups</th>
<th>Name of the genera with species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bivalves</td>
<td>Batissa inflata, B. similis, Codakia tigera, Donax cuneatus, D. lubricus, Gafriarium tupidum, Gelonia galatheae, G. siamica, Paphia malabarica, Perna viridis, Placuna placenta</td>
</tr>
<tr>
<td>Crabs</td>
<td>Cardiosoma carminex, Euricarinus grandieirai, Scylla serrata, Sesarma bidens, S. longipes, Thalamita crenata, T. prynma, Uca dusumieri, U. vocans</td>
</tr>
<tr>
<td>Gastropods</td>
<td>Lambis lambis, Strombus erythrinus, S. variabilis</td>
</tr>
<tr>
<td>Shrimps</td>
<td>Penaeus indicus, P. monodon, P. semisulcatus</td>
</tr>
<tr>
<td>Trilobites</td>
<td>Carcinocrepios rotundicauda</td>
</tr>
</tbody>
</table>
cunnesius, and so on. Fishes also spend their lives restricted to the mangrove habitat because they find both food and shelter here. Certain amphibious mud-skipper fishes such as *Apocryptes bato*, *Brachygobius nanus*, *Boleophthalmus dussumieri*, *Periopthalmus koelreuteri*, *P. vulgaris*, etc., inhabit the muddy floors. A large number of cartilaginous fishes like whale shark, tiger shark, hammer-headed shark, sting ray, saw fish, guitar fish, etc., also adds to the species richness of Indian mangrove forests [8].

Amphibian diversity is comparatively low in this ecosystem. Among amphibians, frog species such as (such as *Rana cyanophlyctis*, *R. hexadactyla*, *R. limnocharis*, *R. tigrina* and *Microhyla ornata* are mainly found.

Reptiles found in mangroves include the estuarine crocodile (*Crocodylus porosus*), dog-faced water snake (*Cerberus rhynchops*), chittul (*Hydrophis cyanocinctus*), valakadiyan sea snake (*Enhydrina schistosa*), python (*Python molurus*), etc. Also agamid (*Calotes versicolor*), water monitor lizard (*Varanus salvator* and *V. flavescens*), turtles (such as *Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, *Pelochelys bibroni*, etc.) and terrapins (*Batagur baska*) are encountered.

Mangrove forests are ideal sanctuaries for avifauna. They use mangroves as roosting, breeding and feeding sites. Birds found in these ecosystems include little cormorant (*Phalacrocorax niger*), grey heron (*Ardea cinerea*), egrets (such as *Egretta alba*, *E. garzetta*, *E. intermedia*), grey pelican (*Pelecanus philippensis*), blue kingfisher (*Alcedo athis*), white-breasted kingfisher (*Halcyon chloris*, *H. pileata*, *H. smyrnensis*) and pied kingfisher (*Ceryle rudis*), night heron (*Nycticorax nycticorax*), etc.

Mammals are represented by flying foxes, (*Cynopterus sphinx*, *Pteropus*, *giganteus*, *P. melanotus*) otters (*Lutra lutra*), monkeys (*Macaca mulatta*), crab-eating monkeys (*Macaca fascicularis*), spotted deer (*Axis axis*), fishing cats (*Felis viverrina*), and larger mammals like wild boars (*Sus scrofa*) and the Royal Bengal tiger (*Panthera tigris*) (*Figure 8*). Aquatic mammals including gangetic dolphin

*Figure 8. The Royal Bengal tiger (Panthera tigris tigris) is the flagship species of the Sunderban mangrove forest.*
(Platinta gangetica), snubfin dolphin (Orcella brevirostris) and black finless porpoise (Necmeris porosus) are also found in the rivers near the estuary [9].

**Endemic and Endangered Species**

In our country some mangrove plant species are rare, endemic and restricted to specific saline habitats [5]. *Agalia cuculata, Brownlowia tersa, Heritiera fomes, Merope angulata* and *Tylophora tenuis* are restricted to West Bengal and Orissa. *Phoenix paludosa, Sonneratia griffithii* and *Xylocarpus mekongensis* are restricted to West Bengal, Orissa and Andaman. *Aegialitis rotundifolia* is confined to West Bengal, Orissa and Andhra Pradesh whereas *Rhizophora stylosa* to Orissa. *Lumnitzera littorea* and *Xylocarpus moluccensis* are restricted to Andaman and *Nypa fruticans* to West Bengal and Andaman. *Acanthus ebracteatus* is confined to Andaman and Kerala. A few endemic species are also found in Indian mangrove ecosystem. *Heritiera kanikensis* is endemic to Bhitarkanika (Orissa), *Rhizophora xannamalayana* to Pitchavaram (Tamil Nadu) and *Urochondra setulosa* is endemic to Gujarat. *Sonneratia apetala* is a rare species in several areas.

In comparison to plants, animals are more vulnerable as well as endangered in Indian mangrove ecosystems. Starting from the lower invertebrates to mammals, most of the species are threat-
Endangered crabs include *Sesarma taeniolata, Uca tetraragonon*; shrimps include *Peneus canaliculatus, P. japonicus*; bivalves include *Gelonia erosa* and so on. Some fishes including sharks and gobid fish (mud skipper) are endangered. Indian mangroves also harbour a good number of rare and globally threatened animals including marine turtles, river terrapins, snakes, monitor lizards, estuarine crocodiles, birds and finally mammals like the otter, mongoose, fishing cat, crab-eating monkey, gangesic dolphin and tiger.

**Mangrove Efficacy**

The mangrove forest is a valuable resource throughout the tropics. The forest products have plenty of traditional and direct usages as timber, firewood, charcoal, building materials, tannin and foods in the form of fish, crabs, prawns, molluscs and honey.

*Heritiera minor, Xylocarpus granatum and Rhizophora mucronata* produce very hard and termite-resistant wood that are used in making carts, boat hulls, masts and oars. Trunks of *Bruguiera, Ceriops, Rhizophora* and *Sonneratia* are employed as poles and rafters in constructing houses. Generally mangrove woods are not very important as timber because they split and warp when dried. These woods also have high density (see Table A in Box 3). Today there is considerable demand for showpieces made from drift wood and other small wood derived from the mangrove forests [2].

In India mangrove woods have a large number of genera such as *Rhizophora, Avicennia, Ceriops, Bruguiera, Sonneratia*, which are preferred as fuel wood that has high calorific value (see Table B in Box 3).

Fresh and moist bark of mangrove plants is potential source of tannins. Certain species that can be used as the source of tannin are *Bruguiera cylindrica, B. gymnorrhiza, B. parviflora, Ceriops tagal, Kandelia candel, Rhizophora apiculata, R. mucronata Sonneratia alba, S. caseolaris, Xylocarpus mekongensis* and *X. moluccensis* [11].
Young shoots of a halophytic fern *Acrostichum aureum* are used as vegetables. Propagules of *Bruguiera cylindrica* and *B. parviflora* are eaten by Jarwa tribe of Andaman. Ripe fruits of *Phoenix paludosa* are edible. Commercial ‘keora water’ is made from the distillation of *Sonneratia apetala* fruits [2]. Besides, the inflorescence of *Nypa* palm can be tapped before blooming to collect a sugary sap that can be used for the manufacture of alcohol and vinegar.

Mangroves are excellent feed for cattle. They are also used in traditional medicine [2]. Decoction of *Avicennia officinalis* leaves is used to treat stomach and urinary disorders. The leaf extract of *Rhizophora apiculata* is administered to treat hernia. Leaves of *Bruguiera cylindrica* appear to have tumour-inhibiting property [12]. In Andaman Islands, decoction of shoots of *Ceriops tagal* is used in treatment of malaria. The resin of *Avicennia alba* wood is used for birth control. *Acanthus ilicifolius* (Figure 11) fruits are used for treating kidney stones. Seeds of *Heritiera littoralis* are used in diarrhoea and dysentery. The astringent properties of *Ceriops decandra* and *Xylocarpus granatum* bark are commonly used in dermatology. Barks of *X. granatum* and *X. moluccensis*
are used in treatment of dysentery [11]. Latex of *Excoecaria agallocha* is employed to treat toothache. Large leaves of *Phoenix paludosa* and *Nypa fruticans* are used by local people for thatching huts as well as in wicker work.

Aquaculture of oyster, crab, prawn, seaweeds and finfish culture is practised in mangrove areas without destroying or degrading the natural ecosystem. In the mangrove forests, honeybee nests are very common.

Mangrove forests reduce the fury of cyclonic storms and gales and minimize the effect of the rising of sea level due to global warming. These plants prevent coastal erosion, help in reclaiming land from seas, as well as purify water by absorbing pollutants including harmful heavy metals.

**Uncertain Future**

Mangrove forests are rapidly disappearing throughout the world. The depletion of mangroves is a cause of serious environmental and economic concern to many developing countries including India. Indiscriminate exploitation of wood and non-wood forest products is disrupting mangrove ecosystems.

Some natural factors also regulate the survival of mangroves. Each species of mangrove lives under specific ecological conditions [2]. For instance, increasing salinity of water and soil as well as the daily duration of submersion cause mortality of mangrove plants. Moreover, excessive silting sometimes leads to serious problem as the raising substratum due to sedimentation, suffocates the trees [1]. The pneumatophores of a dead tree decompose rapidly and the silt that was held amongst them gets washed off resulting in the erosion of the coastline [2]. For a mangrove to survive, constant and adequate input of nutritive elements is needed. However, on account of tidal action, a large part of the organic matter produced by the trees is washed away that can also result in depletion of nutrients to this fragile ecosystem [1]. Massive storms and cyclones also affect mangrove growth.
Epilogue

Existence of mangrove is necessary for our very own existence. It is everyone’s duty to think rationally and ethically on the sustainable use and conservation issue of mangroves. After all we cannot outstrip such natural wonder.

Suggested Reading