# Importance of Mangrove Forests of India

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## Abstract

*Mangrove forests in India are unique to have spectacular coverage both in wet and arid coasts of the country with a record of 4011 biological species including the globally threatened species. In spite of growing threats, the mangrove area has been well protected in the last two decades due to strong policy, legal framework and governance. There are 38 areas of mangrove forest in the country under implementation of management action plan, with 100% financial support by the Ministry of Environment and Forests, Government of India. There is a great need to monitor the mangrove and other coastal habitats for growing issues of climate change and sea level rise and for evolving strategies of coastal disaster management.*


## Introduction

Mangrove forests are the coastal rainforests. These are among the world's most productive ecosystems, situated at the interface between land and sea in tropical and subtropical latitudes. The mangroves are the only tall tree forest on the Earth where land, freshwater and sea mix together. They are also known as 'tidal forests' or 'coastal woodlands', specially adapted to survive in harsh interface between land and sea and in conditions of high salinity, extreme tides, strong winds, high temperatures, low oxygen and muddy soil. They are gifted with arching roots, breathing roots, salt-vomiting leaves, mud-dancing fishes and breath-taking beauty. Biomass in mangroves is greater than any other aquatic systems.

The mangrove forests are of great environmental significance and socio-economic value: (i) protecting shores from wind, waves and water

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currents, (ii) preventing soil erosion and siltation, (iii) protecting coral reefs, seagrass beds and shipping lanes, (iv) supplying wood and other forest products, (v) providing habitats and nutrients for a variety of organisms, and (vi) supporting coastal fisheries and livelihoods. Their monetary value is about 0.5 million rupees per hectare per year and this is greater than that of coral reefs, continental shelves and/or the open sea (Kathiresan and Bingham, 2001; Kathiresan and Qasim, 2005). In south India, a mangrove species 'Thillai' is worshipped as a 'temple tree' at Chidambaram.

Global mangroves have an estimated cover of 15.2 million hectares (FAO, 2007), of which about 90% are present in developing countries, but are nearing extinction in 26 countries. Their long term survival is at great risk due to fragmentation of the mangroves, with the ecosystem services offered by them in danger of being totally lost within 100 years (Duke *et. al.*, 2007). The mangrove habitats continued to disappear globally at a rate of 0.66% per year during the period of 2000-2005 (FAO, 2007). It is in this context, flora and fauna of the mangrove ecosystems of India are mostly at threat (Rao *et. al.*, 1998). The actual number of flora that exists in different regions of India is not fully known due to scattered data, the absence of their comprehensive compilation and lack of extensive field surveys.

**Mangrove forest cover in India**

Mangroves in India are spread over an area of 4,639 sq. km, occupying only 0.14% of the geographical area of the country but represent about 3 % of the global and 8% of Asian mangrove coverage (SFR, 2009; FAO, 2007). About 60% of the Indian mangroves are lying on the east coast along the Bay of Bengal, 27% on the west coast lined with the Arabian Sea, and 13% on Andaman and Nicobar Islands. This differential distribution can be attributed to two reasons: (i) the east coast has long estuaries with larger deltas and runoffs due to the presence of mighty rivers, whereas the west coast has funnel-shaped estuaries with an absence of delta formation; and (ii) the east coast has a smooth slope providing larger areas for mangrove colonisation, whereas the west coast has a steep and vertical slope. Most spectacular mangroves are found in Sundarbans in West Bengal with the maximum of mangrove cover (46.39%) in the country, followed by Gujarat (22.55%) and

Andaman & Nicobar Islands (13.26%). In the Andaman and Nicobar Islands, many tidal estuaries, small rivers, neritic islets and lagoons support rich mangrove flora.

Mangrove forest cover in India is classified as very dense, moderately dense and open types based on percentage of its green cover; i.e. >70%, 40-70% and 10-40% respectively. They are very dense in 1,405 sq. km (30.29%), moderate in 1,659 sq. km (35.76%) and sparse in 1,575 sq. km (33.95%). The sparse areas require special attention for increasing the green cover of those areas. Much more area, having the potential for mangrove afforestation is to be identified and promoted for management.

**Table 1**

| State/UT | Year of assessment | | Change of forest cover | |
|---|---|---|---|---|
| | 2005 | 2007 | 2003-2005 | 2005-2007 |
| Andhra Pradesh | 329 | 353 | 0 | -1 |
| Goa | 16 | 17 | 0 | 1 |
| Gujarat | 936 | 1046 | 20 | 55 |
| Karnataka | 3 | 3 | 0 | 0 |
| Kerala | 8 | 5 | 0 | 0 |
| Maharashtra | 158 | 186 | 0 | 0 |
| Orissa | 203 | 221 | 0 | 4 |
| Tamil Nadu | 35 | 39 | 0 | 3 |
| West Bengal | 2118 | 2152 | -2 | 16 |
| Andaman and | 637 | 615 | -21 | -20 |
| Daman and Diu | 1 | 1 | 0 | 0 |
| Pondicherry | 1 | 1 | 0 | 0 |
| Total | 4445 | 4639 | -3 | 58 |

State-wise cover of mangrove forests of India in $km^2$

Source: *Food and Agricultural Organisation* (UN), *2007*

**Trends of change in forest cover:** Mangrove cover showed a net increase of 58 $km^2$ within two years between the years 2005 and 2007. This increase was mainly because of Gujarat which showed an increase of 55 $km^2$ in mangrove cover due to plantations and protection. There was also an increase of 16 $km^2$ in mangrove cover of West Bengal, 4 $km^2$ in Orissa and 3 $km^2$ in Tamil Nadu (Table 1; SFR, 2009).

However, there was a loss of 20 $km^2$ in Andaman and Nicobar Islands, due to the effect of Tsunami in December 2004. This loss was reduced by 1 $km^2$ in the year 2005 due to natural regeneration of mangroves. In general, the mangroves in India have become fairly well protected in the last two decades in spite of growing threats by climate change and man, mainly due to the efforts of Government of India. There are 38 mangrove areas in the country under active implantation of management action plan with 100% financial support by the Ministry of Environment and Forests, Government of India. Mangroves in India are protected through a range of regulatory measures such as Coastal Regulation Zone Notification, 1991; Environmental Impact Assessment studies under EIA Notification, 1994; Mangroves located within the notified forest areas also covered under the Indian Forest Act, 1927 and Forest Conservation Act, 1980.

**Biodiversity of mangrove forests**

Mangroves are rich in genetic diversity due to the occurrence of both aquatic and terrestrial species and their adaptability to a wide range of salinities, tidal amplitudes, winds, temperatures, and even muddy and anaerobic soil conditions. Their habitats are as diversified as core forests, litter-forest floors, mudflats, water bodies (rivers, bays, intertidal creeks, channels and backwaters), adjacent coral reefs and seagrass ecosystems (wherever they occur).

Indian mangroves are diverse with 125 species, comprising of 39 mangroves and 86 mangrove associates. About 56% of the world's mangrove species occur in India, with mangrove associates having 30 tree species, 24 shrubs, 18 herbs, six climbers, four grasses and four epiphytes. Their species diversity is highest in Orissa (101 spp.) followed by West Bengal (92 spp.), Andaman and Nicobar Islands (91 spp.) and lowest in Gujarat (40 spp.).

One among the two genetic paradises in the world is in India at Bhitarkanika of Orissa State, which is not yet explored fully for their genetic diversity. In fact, there is one island namely Kalibhanj dia, adjacent to Dhamra Port in Bhitarkanika, having a total of 101 plant species (31 true mangroves +70 mangrove associates) which is 81% of mangrove species in India in a small area. There are several such areas with rich taxonomic diversity which should be identified and managed as mangrove germplasm preservation centres.

Table 2

| Sl. No. | Groups | No. of Species |
|---|---|---|
| **Flora** | | |
| 1 | Mangroves | 39 |
| 2 | Mangrove associates* | 86 |
| 3 | Sea grasses | 11 |
| 4 | Marine algae** | 557 |
| 5 | Bacteria | 69 |
| 6 | Fungi | 103 |
| 7 | Actinomycetes | 23 |
| 8 | Lichens | 32 |
| **Fauna** | | |
| 9 | Prawns and lobsters | 55 |
| 10 | Crabs | 138 |
| 11 | Insects | 707 |
| 12 | Molluscs | 305 |
| 13 | Other invertebrates | 745 |
| 14 | Fish parasites | 7 |
| 15 | Fin fish | 543 |
| 16 | Amphibians | 13 |
| 17 | Reptiles | 84 |
| 18 | Birds | 426 |
| **Total number of species** | | **4011** |

*Plants that occur in the coastal environment and are also found within mangroves
**Include phytoplankton and seaweeds

Total number of species of flora and fauna reported in mangrove ecosystems of India

Source: Kathiresan and Qasim, 2005

Mangrove forest ecosystems in India support diverse groups of organisms with a total of 4011 that include 920 floral species and 3091 faunal species (Kathiresan, 2000; Table 2); perhaps the largest biodiversity record in the world mangrove ecosystems.

No other country in the world has recorded so many species to be present in the mangrove ecosystem with the faunal species component about 3.5 times greater than the floral component of the mangrove ecosystem. The dense mangrove forests in Sundarbans is unique to have globally threatened species such as Royal Bengal tiger, sea turtles, fishing cat, estuarine crocodile, the Gangetic dolphin and river terrapin. Some wildlife species of mangrove ecosystem, like water monitor lizard and wild boar, are yet to be studied for biology.

**Mangroves of restricted distribution**

Our field study reveals that 11 mangrove species and 8 associates are restricted in distribution. *Acanthus ebracteatus* is known to occur only in the Andaman Islands of India. *Xylocarpus* species are reportedly restricted to Andaman and Nicobar Islands, Sundarbans, Mahanadi delta, Andhra Pradesh and Pichavaram (Banerjee, *et. al.*, 1989; 1998; Naskar and Mandal, 1999; Dagar, *et. al.*, 1991; Kathiresan and Ravikumar, 1993). However, two species, of *Xylocarpus*, *X. mekongensis* and *X. moluccensis*, are seen along the Konkan coast in Achra mangroves on the west coast.

*Brownlowia tersa* which was reportedly restricted from Sundarbans southwards up to Mahanadi delta does occur at Gadapanda in east Godavari District. Some 80 years earlier, this species reportedly grew abundantly nearer to large creeks of Middle Andamans and Dhanikhari creek, but rarely observed there now (Hajra, *et. al.*, 1999).

*Scyphiphora hydrophylacea* is reported from Krishna and Godavari estuaries, Sundarbans, Andaman and Nicobar Islands (Banerjee, *et. al.*, 1989; Naskar and Mandal, 1999). We have located the species in small pockets at Godavari Delta as well as in the adjoining areas of Krishnapatnam harbour.

In Sundarbans, due to reduction in freshwater inputs, the freshwater loving species like *Nypa fruticans* and *Heritiera fomes* have reduced population density. Even species of *Xylocarpus* are becoming rare in Sundarbans due to over-exploitation (Naskar and Mandal, 1999).

**Endemic species of mangroves in India**

To the best of our knowledge, only one mangrove species is known to be endemic one to India, i.e. *Rhizophora x annamalayan*a Kathir., a natural hybrid derived between two species of *Rhizophora* (*R. apiculata* and *R. mucronata*), occurring in Pichavaram of Tamil Nadu (Kathiresan, 1995, 1999). It is confirmed as a new species by using DNA markers (Parani, *et.al.*, 1997). We have recorded only 171 individual trees of the species with a height ranging from 9 to 12 metres, with broad, dark green leaves and robust aerial stilt roots, mostly located between its parental species. This critically endangered hybrid is included in the global list of mangrove species (FAO, 2007).

Another endemic species is *Heritiera kanikensis* that reportedly exists only in Bhitarkanika of Orissa (Majumdar and Banerjee, 1985). Our field visits to the study site at Bhitarkanika and reexamination of both the field specimen and herbarium specimen at Botanical Survey of India, Kolkata, reveal that the species is only *Heritiera fomes*, not a new one. It is further corroborated by the local people of Bhitarkanika mangrove forest who are also of the opinion that there are no new species like *Heritiera kanikensis*, but are only two species namely Heritiera fomes and *H. littoralis*.

**Mangrove species under dispute**

Mangrove taxonomy needs further studies in the field and laboratory, and at molecular levels (using DNA sequence data) for resolving the disputes in identification of species. Rigorous systematic studies are required through assessments of morphological, chemical and genetic variations among mangrove species to develop phylogenetic understanding of individual taxa across their distributional ranges (Duke, 2006). Many specimens identified and indexed as *Acanthus ilicifolius* in Indian herbaria are *Acanthus ebracteatus*, as argued by Remadevi and Binoj Kumar (2000) who observed the presence of this species in marshy areas of Aroor in Alappuzha District of Kerala. However, this identification is questioned by Anupama and Sivadasan (2004). Ecological varieties in *Avicennia marina* and Ceriops tagal need to be recognised. For example, four species of *Avicennia* are locally identified in the Gulf of Kachchh of Gujarat, but it is difficult to relate their local names with botanical names (Singh, 2000). There are several natural hybrids, but their parental species are not clearly understood, especially for the species of *Rhizophora*.

## Globally threatened mangroves in India

Mangroves habitat loss has put at least 40% of the animal species that are restricted to mangrove habitat at an elevated risk of extinction under the International Union for Conservation of Nature (IUCN) categories and criteria. However, none of the global mangrove plant species have been entered in the IUCN Red List. Very recently, assessments of mangrove species were made by 24 global mangrove workers including myself, in two workshops, one in 2007 in Dominica and the other in 2008 in the Philippines. The results published in *PLoS ONE* reveal that 11 of the 70 mangrove species in the world (16%) are at an elevated threat of extinction (Polidoro, *et. al.*, 2010), of which only two species, namely *Sonneratia griffithii* (critically endangered), and *Heritiera fomes* (endangered) exist in India. All other mangrove species in India are in the IUCN category of least concern and only one species, *Brownlowia tersa* is in the category of near threatened species (Kathiresan, 2010).

## Threats and management prescriptions

Mangroves and associates are likely to become vulnerable in near future due to both man-made and natural threats. More widely distributed species such as *Aegiceras corniculatum*, *Acanthus ilicifolius*, *Avicennia marina*, *A. officinalis* and *Excoecaria agallocha*, have great ecological amplitude and remarkable ability of vegetative regeneration. Even these species may decline in near future due to increasing human pressure and climate change.

## Habitat loss and fragmentation

Species with limited salinity tolerance will reduce in populations, interbreeding among those limited populations may reduce genetic vigour and resilience to stress that may likely place the populations at greater risk of local extinction (Duke, 2006). Therefore, it is necessary to protect larger mangrove areas or to improve the extent of mangroves areas, and/or connecting a series of smaller areas.

## Reduction of ecosystem health

Indian mangroves are generally not very healthy, and dense mangrove forests are absent except in three regions, namely Sundarbans (42% dense), Andaman & Nicobar Islands (39%) and Maharashtra (7%). Sparse mangrove forests range from 15 to 96% in different states of the country. Their poor health condition makes the population with reduced genetic vigour, resilience and ability to respond to changing environmental conditions. Also, the poor health of plant will lead to loss of reproductive potential and regenerative capability. 'Top dying' disease of mangrove trees is an example leading to drying and death of leaves and branches from top to bottom with reduced wood productivity. It is, therefore, necessary to find out the factors responsible for poor health, and then overcome them for converting the population healthy.

**Poor natural regeneration**

Propagules are abundantly produced in most of the mangrove forests, but their dispersal, survival and establishment are of serious concern. Dispersal of the propagules is restricted by both land barriers blocking current flow and wide expanses of water (Duke, 2006). Therefore, it is necessary to assess natural regeneration for its constraints like terms of hydrological changes from upstream to downstream areas, and to implement correction measures for facilitating the dispersal and establishment of mangrove propagules.

**Effect of climatic change**

A growing threat to global mangrove ecosystem is the climate change, associated with increasing temperature, changing hydrologic regimes, rising sea level, and increasing magnitude and frequency of tropical storms and natural calamities like Tsunami. To these changes, mangroves are likely to be one of the first ecosystems to be affected, especially in low-lying areas, because of their location at the interface between land and sea. In Indian Sundarbans, two islands, namely Suparibhanga and Lohacharra have recently submerged and a dozen other islands on the western end of the inner estuary delta are under the threat of submergence (*The Daily Star*, December 22, 2006). As the sea level rises, mangroves would tend to shift landward. Human encroachment at the landward boundary, however, makes this impossible. Consequently, the width of mangrove systems would be likely to decrease with the sea level rise. This habitat loss might cause a gradual depletion of the rich biodiversity of mangrove forest flora. However, a few genetically superior plant species, which can overcome any climatic change, do exist in the mangrove habitats, which have to be identified, propagated and introduced in the areas that are vulnerable to natural calamities and sea level rise. Further research is recommended to record plant species with details of their flowering, germination, propagation, growth as related to changing climatic (Kathiresan and Faisal, 2006) to determine the climate change-induced effects on mangrove species.

**Potential impacts of climate change**

**Effect of changes in temperature:** Mangroves are not expected to be adversely affected by the projected increases in sea temperature of 26°C by 2100. However, temperature greater than 35°C may alter root structure and seedling establishment, and the photosynthesis may be affected at 40°C. At the same time, an increased sediment temperature may increase growth rates of bacteria which are likely to increase the recycling and regeneration of nutrients.

**Effect of changes in carbon dioxide:** Increase in $CO_2$ is also not likely to cause any increase in mangrove canopy photosynthesis, but it may increase the rate of net photosynthesis and growth rate of mangroves when the soil salinity is low. The advantage is the water use efficiency by mangroves by reducing the water loss via transpiration; this advantage will be lost when the salinity increases in arid regions.

One indirect effect of the increase of temperature and $CO_2$ is the degradation of coral reefs due to mass bleaching and impaired growth. As a result, protection function of coral reefs from wave action will be lost, thereby affecting the mangroves.

The mangrove wetlands are efficient habitats for carbon burial, about 2.4-fold as high as saltmarshes and 5.2-fold as high as seagrasses. The mangroves sequester as much as 50 times the amount of carbon in their sediment per hectare of tropical forest. More studies are required on the role of microbes in carbon sequestration of the coastal vegetated habitats. In this regard, photosynthetic anaerobic bacteria in the coastal wetlands deserve a serious research attention.

**Effect of change in precipitation:** Precipitation may increase by 25% by 2050 due to global warming. This may result in increase of mangrove area, as well as growth rates and diversity of mangrove zones. However, the precipitation varies unevenly at regional scales either increase or decrease.

**Effect of changes in hurricanes and storms:** There may be 5-10% increase in intensity of storms by 2050. This will affect mangrove health and species composition due to changes in salinity, recruitment, inundation and changes in wetland sediment budget. Storm surges can also flood the mangroves and may destroy them in combination with sea-level rise. *Avicennia* species are more vulnerable than *Rhizophora* species, mainly due to stilt roots of the latter which stands above sea-level than the pneumatophores of the former which remain mostly submerged. Moreover, stilt roots trap sediments and facilitate peat accumulation in the mangrove areas.

**Effect of changes in Sea level rise:** Sea level rise is the greatest climate change that the mangroves face. They can adapt to it if it occurs slowly enough, if the rate of sediment accretion is sufficient to keep with sea level rise and if adequate expansion space exists without any interference caused by infrastructure (*e.g.*, roads, agricultural fields, dikes, urbanisation, seawalls and shipping channels) and topography (*e.g.*, steep slopes). Tidal range and sediment supply are two critical indicators of mangroves, response to sea level rise. The mangroves with macro-tidal and sediment rich areas are able to survive sea level rise than those with micro-tidal and sediment starved areas.

The most vulnerable mangroves to sea-level change are located in areas with small islands, lack of rivers, carbonate settings, tectonic movements, groundwater extraction, underground mining, micro-tidal and sediment-starved areas, and with coastal development and steep topography. The least vulnerable mangroves are situated in riverine areas, macro-tidal and sediment rich areas, and dense mangrove forests.

**Strategies to mitigate climate change effects**

1. **Protection of species and habitats:** To mitigate the risk of losing mangroves to sea-level rise, it is necessary to identify and protect critical areas, species and also sources of propagules to ensure replenishment following disasters.

2. **Management of man-made pressure:** Mangroves have to be protected from anthropogenic pressures by implementation of management practices through provision of sustainable and alternative livelihood to the mangrove-dependent people.

3. **Establishment of green belts and buffer zones:** It is necessary to raise green belts along open coast, river banks/lagoons and islands/creeks/channels with a mangrove greenbelt width of 100 -500 m, 30-50 m and 10 m respectively for coastal protection from erosion. It is also necessary to maintain buffer zones bordering the seaward and landward margins of protected mangroves to provide a transition between human inhabitation and natural environment either landward or seaward.
4. **Restoration of degraded areas:** This can be done by (i) hydrological manipulation through construction of creeks, thereby flushing the degraded areas with tidal waters, (ii) community participation, and (iii) integrated farming practices.
5. **Connectivity of mangroves with other systems:** This can be done by ensuring the linkage between mangroves and sources of freshwater and sediments, and between mangroves and their associated habitats like coral reefs and seagrasses.
6. **Baseline data development:** It is required to establish baseline data on forestry structure, species richness, abundance and diversity of flora and fauna, primary production nutrient and hydrological aspects for monitoring the response of mangroves to climate change.
7. Establishment of partnerships at local, regional and global scales

## Conclusions

Mangroves are uniquely adapted coastal plants of great ecological and economic significance. They act as a natural barrier against severe storms, and they significantly reduce deaths, livestock loss and property damage. In October 1999, Orissa was battered by the super cyclone that killed almost 10,000 people and caused a massive loss of livestock and property. The loss of human life caused by the storm was directly linked to the removal of the natural defence provided by mangroves. Similarly, the role of mangroves in coastal protection against the 26$^{th}$ December 2004 Tsunami was remarkable. Mangrove and casuarinas plantations reduced Tsunami-induced waves and protected shorelines, human lives and properties against damage in southeast Tamil Nadu (Kathiresan and Rajendran, 2005; Danielsen, *et. al.*, 2005). Mangroves also enhance fisheries and forestry production, and these benefits are not possible with concrete coastal protection structures. Moreover, the establishment and maintenance of coastal vegetation incur only low cost as compared to concrete structures used for coastal protection. Besides providing coastal protection, they are also known for ecological and livelihood benefits, as well as efficient carbon sequestration. Therefore, raising the coastal mangroves as a bio-shield is a priority task.

Bioprospecting of mangrove ecosystems, in search of valuable products and genes, is of growing interest in India. They are the promising source of valuable products such as black tea-like beverage, mosquito repellents, enzymes, pigments, nanoparticles, microbial bio-fertilisers, bio-feed, single cell proteins, and medicines to cure dreadful human diseases like AIDS and cancer. The M.S. Swaminathan Research Foundation has isolated salt-tolerant genes from the mangrove species *Avicennia marina*, and introduced it into a paddy crop (Pusa Basmati and IR64) via *Agrobacterium*. The salt tolerant paddy variety is under experimental trial. With the increasing seawater intrusion due to coastal climate change, it is necessary to find out high salt tolerant genotypes of mangroves. This will have a bearing on resilience and recovery of mangrove species under changing coastal climatic conditions.

With the increasing seawater intrusion due to coastal climate change, it is necessary to record plant species with details of their flowering, germination, propagation and growth, as well as the behaviour of animals to determine the climate change-induced effects on the biological species of mangrove ecosystems. The mangrove habitat in India is proved efficient in carbon sequestration, 2.4-fold as high as saltmarshes, 5.2-fold as high as seagrasses and 50 times as high as tropical forests. Occupying just 0.29% of Indian coastal area, the mangroves are contributing to 2.2% carbon burial. Therefore, mangrove restoration can be a novel counter-measure to global warming.

Mangroves in India are likely to absorb, and respond to, change and disturbance of climate change. This calls for intensive attention on managing the mangroves for resilience to climate change through implementation of adaptation strategy such as (i) to identify salinity and flood tolerant species and to plant them in the sites which are vulnerable to salinity and sea level rise , (ii) to record the plant species with details about their flowering, fruiting, germination, propagation, growth and evaporation demand as related to climate change, (iii) enhancing the density of mangrove stand, diversifying the mangroves using most adaptable species, amendment of substrates for favourable colonisation of mangroves.

It is necessary to collate comprehensive species-specific information for mangroves of India, in absence of which it will be difficult to identify and implement conservation priorities. It is a matter of urgency to protect and propagate the two globally threatened species, *Sonneratia griffithii* and *Heritiera fomes* which are growing in India, in order to increase their population size in their habitats. Research intervention is required to overcome the problem of low seed viability in those species, as well on the natural hybrids that occur in the families of *Rhizophoraceae* and *Sonneratiaceae*, and also on the ecological varieties of *Avicennia marina* and *Ceriops tagal*. Further studies are required on the discontinuous distribution and occurrence of mangroves along the coastal India.

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