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Present Status on Distribution, Biodiversity and Management of Indian Mangroves

Udai Ram Gurjar[1*], Suman Takar[2], Khemraj Bunkar[1], Vikas Pathak[1] and Jaspreet Singh[3]

[1]ICAR-Central Institute of Fisheries Education, Mumbai, Maharashtra (400 061), India
[2]Fisheries College and Research Institute, Thoothukudi, Tamil Nadu (628 008), India
[3]ICAR-Research Complex for Eastern Region, Patna, Bihar (800 014), India

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Corresponding Author
Udai Ram Gurjar
e-mail: urgurjars968@gmail.com

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Abstract

Globally, mangroves are one of the most productive and threatened ecosystems situated within the intertidal zones of tropics and subtropics. Mangrove ecosystem of India is unique with the highest record of biodiversity, gifted with the mangrove genetic bliss at Bhitarkanika, and wildlife threatened species in the Sundarbans. They act as a guardians of juvenile stock and important source of livelihood for coastal communities and protect from storm surges and tsunami. Mangroves are also a great source for carbon sinks and sequester the high amount of CO_2. Mangrove ecosystems are vulnerable to various anthropogenic actions such as industry, agriculture, solid waste dumping, aquaculture ponds, construction of buildings and infrastructures. In recent years, the conservation of mangrove reserves and habitats has assumed great significance in developing countries. This article deals with the present status of mangroves biodiversity, conservation and management strategies for restoration of these fragile ecosystems.

1. Introduction

Coastal ecosystems are areas where land and water join to create an environment with distinct structure, diversity and flow of energy. They include several ecosystems such as salt marshes, mangroves, coral reefs, seagrass, etc. Of these, mangrove ecosystem is particularly significant, from both the ecological and economical points of view. The word "Mangrove" is considered to be a combination of the Portuguese word "Mangue" and the English word "grove". Duke (1992) defined mangroves as a group of a tree or shrub or palm or ground fern and/or a grass, exceeding half of a meter in height and growing above the mean sea level in the intertidal zone of marine coastal environment or estuary margin in the tropical and subtropical coastal regions. Mangrove forest is the only forests situated at the confluence of land and sea in tropical and subtropical latitudes, also is one of the biologically diverse ecosystems in the world, rich in organic matter and a nutrient which support very large biomass of flora and fauna. They provide valuable sociological and economic goods and services to human (Bennett and Reynolds, 1993, Clough, 1993). The energy flow through the nutrients from land to the sea and enrichment due to the detritus formation makes mangrove ecosystems rich relative to the primary and secondary production. The long coastlines and mangrove forest have huge role in protecting coastal community and biodiversity. This fragile ecosystem covered almost 47% world's mangrove area with 85% world's mangrove species from different habitations having an imperative role in coastal biodiversity of 30 countries that bordered the Indian Ocean (Kathiresan and Rajendran, 2005). Mangrove ecosystems provide numerous employment opportunities to the local communities and augment their livelihood. Also provides huge numbers of people with food, tannins, fuel, wood construction materials and even medicines. Timber is one of the biggest forest products. In many countries including India subsistence fisheries activities are mostly depends on healthy mangrove forests. They support the conservation of biological diversity by providing habitats like breeding and nursery grounds for a variety of marine animals such as invertebrates, fishes, reptiles, birds and even mammals like tiger as well as a potential source for recreation and tourism (Macintos and Ashton, 2002). They are also known as Kidneys as they purify air and water by absorbing impurities and harmful heavy metals. They have the ability to sequester and store huge amounts of carbon, plays an important role in global carbon budgets and in the process of mitigating climate change. That means mangroves are among the most carbon rich forests in the tropics.Globally, mangroves are one of the most threatened ecosystems, which pose serious

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threats to the ecosystems around the map and silently become one reason for global warming as well as sea level rise. The mangrove forest and its associated flora and fauna are destroyed mainly by anthropogenic activities in different forms. The first and most is the conversion of mangrove area to agriculture, aquaculture, tourism, urban development etc. (Alongi, 2008). The mangroves are under ecological and man-made pressures. The cumulative effect of natural calamities, clear-cutting, over-logging, fish and shrimp farming, industrial and domestic pollution, dredging, reclamation for industrial and agricultural expansions and habitat fragmentation threaten their continued existence. Increased flooding, loss of local subsistence and declining fisheries may lead coastal communities to undergo severe social and economic hardships. It is necessary to undertake management plans to conserve the mangroves for protecting the shoreline and terrestrial ecosystems from high velocity tides and tsunamis. With increasing destruction and degradation, it is critical to understand the mangrove and its associated biodiversity for the present status and future actions required for effective management. In this regards, conservation and restoration of this extremely fragile ecosystem have become a serious issue, to all stakeholders.

2. Distributions of Mangrove

2.1. Global mangrove distribution

Globally, 156,220 km^2 area is cover by mangrove forest out of which largest amount of world's mangrove 62,880 sq. km in Asia, 30,270 sq. km in Africa, 23,870 sq. km in North and Central America, 21,610 sq. kmin South America and 17,590 sq. km in Oceania (Table 1). Indonesia alone constitutes 23% of global mangrove forest followed by Australia (7.1%) and Brazil (7%). Food and Agriculture Organization of the United Nations assessed reduction in mangrove cover by 18% within a period of last three decades. In Asia, Africa, Oceania and North and Central America, mangrove cover was reduced by 19%. Whereas, mangrove cover was almost remain unchanged in South America where reduction is lowest by 2.8% (FAO, 2010). The most extensive area of mangrove forest is found in South East Asia followed by South America, North Central America and West and Central Africa. South Asia covers 10,344 sq km which is constitute 6.8% of world's mangrove forest, out of which contribution of India is 45.8% of the total mangrove cover in South Asia (Figure 1).

Table 1: Periodic change in global distribution of mangrove cover

Location	Assessment Year (Area in sq. km)					% change
	1980	1990	2000	2005	2010	
Asia	77,690	61,960	66,270	64,660	62,880	-19
Africa	36,700	34,140	31,780	31,020	30,270	-17
North and Central America	29,510	24,160	23,100	23,420	23,870	-19
Oceania	21,810	18,600	18,410	15,370	17,590	-19
South America	22,220	22,250	21,870	21,750	21,610	-2.8
Total	189,910	161,110	161,430	156,220	156,220	-18

Source: FAO (2007 and 2010)

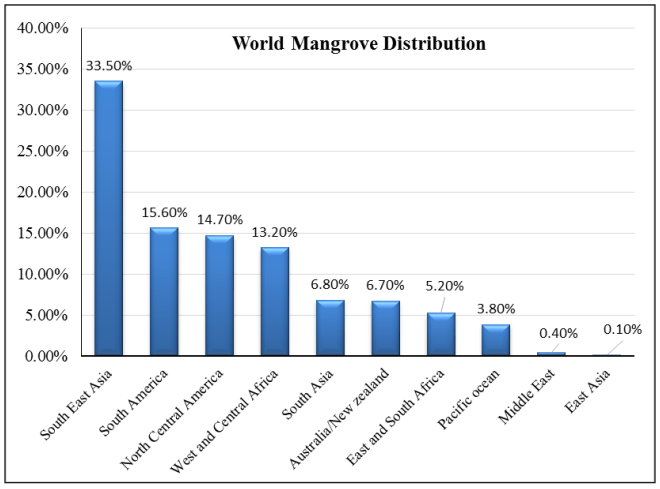

Figure 1: World mangrove distribution

2.2. Indian mangrove distribution

The mangrove ecosystem is generally of three types, in which the first being the deltaic mangroves situated along the mouth of major estuaries on east coast and Gulf of Kachchh and Gulf of Khambhat on the west coast. These cover up to 53% of the total Indian mangroves out of which Sunderbans cover about 78%. Second types are the coastal mangroves which are found along the intertidal coastlines, sheltered bays, minor river mouths, and backwater areas of the west coast which is constitute 12% of the mangrove area of country and lastly the island mangroves which are found along shallow protected intertidal zones of Lakshadweep and Andaman & Nicobarislandswhich is constitute approximately 16% of the total mangrove area of India (Ingole, 2005). India had a mangrove cover of 6000 sq. km during the year 1960s, and it has reduced by 18%, i.e. 4921 sq. km. India with a long coastline of about 8118 km.Mangrove habitat covers an area of 4921 sq. km along Indian coastlines which is 0.15% of the

country's total area and comprises of 3.3% of the world's mangrove forests (FSI, 2013; 2017) (Table 2). These include 1,351 sq. km of very dense, 1,457 sq. km of moderate and 1,819 sq. km of open mangroves. Indian mangrove forest was increased over the last two decades concurrent with the strict conservation and afforestation program implemented by the Government of India to recover from the decline during 1990's (FSI, 2013). According to ISFR 2017, total mangrove cover stands at 4,921 km^2 and has increased by 181 km^2 in India. 7 out of 12 mangrove states have shown an increasing trend in mangrove cover while none of the states show any negative change. Maharashtra (82 km^2), Andhra Pradesh (37 km^2) and Gujarat (33 km^2) are top three gainers in terms of mangrove cover area is mainly due to conservational effort such as plantation and regeneration of mangroves.

Table 2: Distribution of mangrove vegetation cover in different maritime states and union territories of India (FSI, 2017)

State/UT	Assessment Year (Area in sq. km)								Change of cover area between 1987 and 2017 (in % or fold)
	1987	1993	1999	2005	2011	2013	2015	2017	
West Bengal	2,076	2,119	2,125	2,136	2,155	2,097	2,106	2114	+1.83%
A&N islands	686	966	966	635	617	604	617	617	-10.05%
Andhra Pradesh	495	378	397	354	352	352	367	404	-18.38%
Odisha	199	195	215	217	222	213	231	243	+22.11%
Tamil Nadu	23	21	21	36	39	39	47	49	+113%
Puducherry	0	0	0	1	1	1	2	2	+2 fold
Gujarat	427	419	1,031	911	1,058	1,103	1107	1140	+167.98%
Maharashtra	140	155	108	186	186	186	222	304	+117.14%
Goa	0	3	5	16	22	22	26	26	+ 26 fold
Daman & Diu	0	0	0	1	2	1.63	3	3	+3 fold
Kerala	0	0	0	5	6	6	9	9	+9 fold
Total	4,046	4,256	4,871	4,500	4,662	4,628	4740	4921	+21.63%

2.3. Mangrove and associated flora and fauna

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. Globally, mangroves are classified into 73 species of trees and shrubs, highest species diversities found In Asia (39%) followed by Eastern Africa (21%), North and Central America (15%), South America (12.6%) and Oceanica (12.4%). About 80% of fish catch is depended on the mangrove forest (Sandilyan and Kathiresan, 2012).

Globally, India has the highest record of biodiversity in mangrove ecosystems. Total 4107 species including 23% of flora and 77% of fauna species have been recorded from India. In which eight groups of organisms are dominant by more than 100 species and they are mangrove species (true mangroves + mangrove associates), marine algae (phytoplankton + seaweeds), fungi, crabs, mollusks, insects, other invertebrates and finfish (Table 3) (Kathiresan, 2017). In India, total of about 41 genera belong to 29 families of mangrove plants had been reported by Duke (1992). Ray *et al*. (2000) studied on planktonic and benthic animals having a major role in the mangrove ecosystems like the terrestrial animals. Benthic organism constituted an important component of the food web of ecosystems. Mangrove areas serve as feeding, breeding and nursery grounds for many commercially important shellfishes and finfishes, in addition to providing shelter for the juvenile stages of these groups (Rajagopalan *et al.,* 1986). Venkataraman and Wafar (2005) reported 1,862 species of mangrove and associated fauna that included 8 species of oysters, 7 species of clams, 6 species of pearl oysters, 4 species of giant clams, 1 species of window pane oyster and other gastropods such as sacred chank, trochus, and turbo as well as 15 species of cephalopods from the Indian marine region. Kathiresan and Qasim (2005) observed that the total number 3,111 of mangroves faunal species inhabitants in mangroves area, which include prawns, crabs and molluscs, fishes, fish parasites, insects, reptiles, amphibians, mammals etc. There were about 18 species of brachyuran crabs under 9 genera and 4 families were identified and reported from Sunderban mangrove ecosystems by Chakraborty and Choudhury (1992). 11 different groups of zooplankton was assessed in the mangrove along Mumbai coast which is important prerequisite for ecosystem modelling and rational management (Takar *et al.*, 2018). Khade and Mane (2012) reported 12 species of bivalves and 13 species of molluscs from Ratnagiri coast of Maharashtra. Total of 55 species of molluscs represented 13 orders, 30 families and 39 genera from the mangrove are of Uran (Pawar, 2012). Solanki *et al.* (2016) studied mangrove ecosystems of Ghogha coast, Gulf

Table 3: Total number of mangrove associated flora and fauna species in India (Kathiresan, 2017)

Sl. No	Groups	No. of Species
Floral groups		
1.	Mangroves	44
2.	Mangrove associates*	86
3.	Sea grasses	11
4.	Marine algae**	557
5.	Bacteria	69
6.	Fungi	103
7.	Actinomycetes	23
8.	Lichens	32
Total floral species		925
Faunal groups		
9.	Prawns and lobsters	55
10.	Crabs	145
11.	Insects	661
12.	Molluscs	337
13.	Other invertebrates	745
14.	Fish parasites	7
15.	Fin fish	554
16.	Amphibians	13
17.	Reptiles	84
18.	Birds	513
19.	Mammals	68
Total faunal species		3182
Total number of species		4107

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

of Khambhat, where they were observed total 71 marine fauna, 42 avian fauna from 31 genera and 12 families, 14 species of crustacean from 13 genera and 10 families, 9 species of molluscs from 8 genera and 7 family and 3 species of Mudskippers. Nagelkerken *et al.* (2002) studied mangroves to transform into detritus, which was partially supported the ecosystem food web. As it is providing abundance of food, shelter and low predation pressure makes the mangrove forest an ideal habitat for variety of animal species during part and/or entire life cycle. But Alongi (2008) stated that the contribution of detritus from macro-algae, benthic microalgae, phytoplanktons and epiphytes was generally low in most mangrove forests because of the light limitation under the canopy. Gopal and Chauhan (2006) recorded 350 species of vascular plants, 250 fishes, 300 birds, planktons as well as mammals from Sunderban region, where mangrove species of *Heritiera fomes* (locally called Sundari tree, hence the name Sundarban), *Nypa fruticans* and *Phoenix paludosa* are declined rapidly. During the past three decades large parts of the Sundarban had been protected as sanctuaries and biosphere reserve particularly for the white tiger. Tripathy *et al.* (2013) studied inland mangrove communities *Avicennia marina* representing only sacred grove species as the world's inland mangroves. The inland mangrove in Shravan, Kavadia and Kachchh were most important sacred groves of Gujarat for the local inhabitants.

2.4. Ecological and economic value of mangrove

Mangrove ecosystems provide excellent nesting and breeding habitats forfishes and shellfishes, migratory birds and sea turtles, emphasizing their importance to coastal fishing communities. 90% of marine organisms spend entire or some portion of their life cycle within the mangrove ecosystems (Adeel and Pomeroy, 2002). Mangroves are also great source for carbon sinks. They isolate carbon at two to four times more than the rate oftropical forests like the Amazon and store three to five times more carbon per equivalent area than tropical forests. Mangroves forests which act as effective carbon sinks and sequesters high amount of CO_2 which were observed average 100 tons per hectare (Harty, 1997). Alongi (2012) observed approximately 3% of carbon sequestered by mangrove forest, might be less than 1% of the total area of tropical forests. Mangrove areas generate emission of 0.002-0.012Pg carbon/year that was virtually 10% of global emissions which account about 0.7% of tropical forest area (Donato *et al.,* 2011).The annual economic values of mangroves, the cost of products and services provide had been estimated to be about US $ 200,000 to 900,000 per hectare Wells *et al.* (2006). Spalding *et al.* (1997), Walters (2004) and Tarakanadha *et al.* (2013) observed mangroves were direct harvest to meet subsistence needs, fuel and construction materials. Ecosystem is important as income supplement for coastal community, also providing partly to fulltime occupation for coastal community.

2.5. Factor affecting mangrove ecosystem

Mangroves play a vital role in many aspects of our daily life but these ecosystems are vulnerable to various anthropogenic activities and climate change. The primary threats to mangrove ecosystemis due to various anthropogenic actions, like reclamation for various purposes such as industry, agriculture, sand landing, solid waste dumping, persistent organic pollutants, aquaculture ponds, construction of buildings, roadand bridges violating the CRZ regulation (Borkar *et al.,* 2013). Ewel *et al.* (1998) studied on mangroves loss and observed if, loss of mangroves due to degradance of coastal water quality, fertility, loss of biodiversity, eliminate fish and crustacean nursery habitat as well as eliminate major resources, numerous goods and services. The impacts of human activities was major factors contribute

to the widespread loss and the degradation of mangrove ecosystems (Gilbert *et al.* 1998). The mangrove forests is the most threatened among global ecosystems, especially in Asia, and current mangrove areas had fallen below 15 million ha. decreased from 19.8 million ha. in 1980 (Wilkie and Fortuna, 2003). The average global rates of loss in the past two decades vary from 20%. McFadden *et al*. (2007) gave broad scale modeling shows 33% to 44% loss of mangrove from 2000 to 2080 due to an increase of 36 to 72 cm in sea level. 11 of the 70 mangrove species (16%) were at elevated threat of extinction (Polidoro *et al.,* 2010). Particular from the Atlantic and Pacific coasts of Central America, where 40% of mangroves species was threatened with extinction. Factor influencing the biodiversity and community ecology of intertidal zones are often investigated to test hypotheses on the generality of patterns that immersion and other physical and biological factors exert on assemblages (Connell, 1972; Menge and Branch, 2001). Environmental factors play an active role in the biodiversity and ecological function of the mangrove ecosystems. Studies conducted on macro-fauna distribution in mangrove, showed the inter-relationship with the environmental factors (Asthon, 1999). Environmental factors including temperature, salinity, pH and rainfall are the important key determinants that had a strong influence on the growth, survival and distribution of mangroves (Blasco, 1984). The identified cause of the natural degradation of mangroves are mainly due to high salinity, low level of available nutrients, and poor microbial count in the soil substrates (Kathiresan, 2000). Salinity and tidal fluctuations in the mangrove swamps are critical factors that regulate the physical and chemical environment of entire biota of Sunderbans (Pool *et al.,* 1977 and Chakrabarti, 1993). Salinity which was one of the most important factors in mangroves establishment and early development as well as most of the mangroves are facultative halophytes they grow better in some salt but do not necessarily require it for growth (Ball, 2002). Natural hazard like tsunami occurred in 2004 leads to extensive damage of mangroves in the Southern coast of India and Andaman and the Nicobar Island. (Ramachandran *et al.,* 2005). Alongi (2008) observed the global climate change due to deforestation may lead to a maximum global loss of 10 to 15% of mangrove forest but stated that must be considered as secondary importance compared with current average annual rates of 1 to 2% deforestation. Pharmaceuticals and personnel care products and persistent organic pollutants have been identifies potential pollutants in the mangrove environments and these pollutants adversely affecting the ecosystem and biodiversity. The mangrove patches in cities of Mumbai and Kolkata were affected by the discharge of large amounts of solid wastes and effluents from various sources, which made mangrove survival very difficult (Vyas, 2012). The restoration of mangroves which were affected by the local communities for expanding shrimp/fish culture actives, cutting of mangroves for timber/firewood, for construction of boats and other necessaries coupled with the rehabitation of the mangroves dependant fishers communities (Ravishankar *et al.,* 2004).

2.6. Management practices

Mangrove ecosystem is continuously facing a risk from anthropogenic activities and climate change. As a result effectiveconservation and management of these fragile ecosystems is essential for a better environmentally sustainable future (Badola *et al.,* 2012). Ellison (2008) suggested mangrove ecosystem management; increased attention should be given to the role of mangroves in coastal communities that should be ultimately preserved the ecosystems. After, Ramsar convention the legislative protection of mangroves have increased manifold, as it was strongly advocated and incorporated the requirement of mangrove management into National Forest Policy of India. National Mangrove Committee (NMC) as an advisory body to the Govt. of India was formed to comprehensively manage mangroves in the country. In 1987, NMC recognized six major locations in east coast of India, namely Mahanadi delta, Bhitarkanika, Godavari delta, Krishna estuary, Pichavaram and Sundarbans to create awareness among local people through scientific and research program. At present, almost all mangrove habitats of India assured legal protection under Wildlife Protection Act of 1972 and Forest Conservation Act of 1980. In spite of increasing pressures, mangrove forests are fruitfully managed in India by adopting three management strategies: (i) promotory; (ii) regulatory and (iii) participatory. In the promotory approach, the Govt. of India implements the Management Action Plan (MAP) in different 38 mangrove areas, identified all along thecoast. Focus on regulatory approach, India is strong on thepolicy front with sufficient legal provision for mangrove protection in the National Park, Wildlife Sanctuary, Reserved Forests, Protected Forests and Community Reserves; however, effective implementation of the legislations is often constrained by lack of financial and human resources, poor infrastructure and dearth of political will (Kathiresan, 2017). In the participatory management involving all stakeholders mainly from the industrial sectors is essential. In this regard, India has demonstrated the best practices of conservation and management of mangroves, and they are (i) Maharashtra Mangrove Conservation Model; (ii) Canal bank planting with 'Fish Bone' design for mangrove restoration; (iii) Participatory Mangrove Management Modeland (iv) Kannur Mangrove Mission.

Reforestation and conservation activities for mangroves in the central west coast of India was introduced to create public awareness with regards to the importance of mangroves; intertidal mud banks control; biomass increase along the estuaries to influenced the biological productivity and improve bird and animal life (Untawale, 1996). Govt. of Goa has banned felling of 15 species of mangroves according to the Goa, Daman and Diu Preservation of Trees under Act, 1984.

Govt. of India declared these areas as ecologically sensitive areas under the Environment Protection Act, 1986 and CRZ Notification 1991 putting a ban on their exploitation and prohibited development activities in these areas. Ministry had made a plan for conservation and management of mangroves in 1986 and constituted National Committee to advise the Government on relevant the policies and schemes. Based on their recommendations 15 mangrove areas in the country were identified for intensive conservation (Anon, 1997; Jagtap *et al.*, 2002). Nursery and planting techniques vary considerably among mangrove species and the silvicultural methods that depend on the ecosystems (Field, 1999).

3. Conclusion

Present study reveals that mangroves are one of the most threatened ecosystems in the world. They are facing a high risk of destruction due to the continuous increase in anthropogenic activities along with the coastal areas. Rising the global temperature and concentration of CO_2 are likely to increase the productivity of mangrove wetlands, change in the flowering and fruiting time, and migration of mangrove species into higher latitudes. However, agriculture and aqua farming have been identified as a major threat to mangrove destruction. Mangrove act as a breeding and nursing ground for many marine and pelagic species. Appropriate monitoring is commanding to prevent illegal activities such as poaching of woods, fishing activities, movement of barges, etc. so that new generations do not get damaged and depleted. For that restoration of mangrove can be a unique counter-measure for global warming as it reduces huge emission of carbon to the atmosphere. It deserves the attention of policy makers in planning for its utilization in the carbon market and trading. The future of mangroves in India needs restoration of ecosystem services of the mangroves with strong involvement of community participation to mitigate the impacts of climate change.

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