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Status of Indian Mangroves

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Mini Review

Despite the significant ecological and economical services, mangroves have witnessed an annual loss between 0.16 and 0.39%, globally, due to rapid coastal development [1]. In south Asia (also known as Indian Subcontinent), mangrove forests have been lost at an average rate of 0.18% per year [2]. In India mangroves are spread over an area of 4921km^2, which representing 3.3% of the global mangrove vegetation [3]. In contrast to global trend, in India mangrove extent has increased in last decade. The estimates of Forest Survey of India show a net increase of 875km^2 during 1987-2017 when the mean annual change in mangrove extent was 30.21±81.72km^2; the extent of increase was 112km^2 between 2013 and 2015 and 181km^2 between 2015 to 2017 [3].

However, the global mangroves, as well as in India, have witnessed the implicit species loss despite mangrove expansion in many regions [1,4,5]. This calls for the evaluation of our understanding on mangrove dynamics and effectiveness of existing conservation methods and a refinement in them for better management of mangroves. Considering these facts in this text status of Indian mangroves have been discussed.

Mangrove forests in India are found along the coastline of 9 States and 4 Union Territories and it is the third richest country in the world in terms of mangrove species diversity with 46 true mangrove species belonging to 14 families and 22 genera [6]. However, the species diversity of Indian mangroves is under constant flux due to both natural (e.g. erosion, aggradations) and anthropogenic forces, possibly leading to changes in floristic composition and local extinction of some species. For instance, certain mangrove species viz., *Heritiera littoralis, Xylocarpus granatum, Bruguiera cylindrica, Lumnitzera racemosa, Sonneratia caseolaris and Cynometra iripa* are on the verge of extinction in the west coast [7,8].

In east coast, the extent of Heritiera fomes, is estimated to have declined by 76% since 1959 and about 70% of the remaining *H. fomes* trees were affected by the 'top dying' disease [9]. Further, the populations of *Nypa fruticans*, and *Xylocarpus molluccensis* also underwent dramatic declines in Indian Sundarban [10]. Selvam [11] did not observe *Xylocarpus granatum*, *Sonneratia apetala, Kandelia candel* and *Bruguiera gymnorhiza* in Pichavaram mangroves, which were two decades earlier, from the region. About 52% of mangrove species in India have restricted distribution [6] and 9 species are of conservation significance at global level - *Sonneratia griffithii* and *Heritiera fomes* are 'critically endangered; *Excoecaria indica* and *Aglaia cucullata* are 'data deficient'; *Aegialitis rotundifolia*, *Brownlowia tersa*, *Ceriops decandra, Phoenix paludosa* and *Sonneratia ovata* are 'near threatened' [12]. In addition, mangrove floristics of mainland India not explored sufficiently in recent times.

Thus, species identity and distribution remains elusive in mangroves of mainland India. For instance, identity and distribution of *Sonneratia griffithii* in Sundarban and Odisha, Acanthus ebracteatus in Kerala and Odisha, *Avicennia Alba* in Kerala and *Rhizophora stylosa* in Odisha are not clear. Further, certain species like *Aglaia cucullata, Bruguiera sexangula* etc., are not found in the field more than decade. So the extensive floristics studies are precise to provide the correct identity and distribution of mangroves in East and west of India. Furthermore, efforts would be taken to increase the population of species under the risk of extinction or of low abundance.

Information of forest structure is the primary database that provides insight into the specific feature of each mangrove ecosystem. Mangrove stands exhibit wide regional and local variation in their structural characteristics as it is controlled by local site factors including topography, soil properties, and tide fluctuations [13,14] than the climatic factors like rainfall and temperature, which controls the worldwide distribution of mangroves.

Hence, understanding local level forest structure is highly essential for their management. But in Indian context, studies on mangrove forest structure are very limited. Forest structural studies on Indian mangrove forests at Pichavaram and Muthupet [15-17], in Andaman Islands [18-23], in Odisha [24,25], in Andhra Pradesh [26-29], in Kerala [30-35], in Gujarat [36] and in Sundarbans [37-44] are noteworthy. Complexity index (Ic) and

Important value index (Iv) are the structural indices often used to express existences of stress in the forest stand and importance of a tree species within a stand of mixed species respectively. Based on the available literature, it is event that except ANI, all other mangrove habitat in India has low Ic value and *Avicennia marina* constitutes the important tree species, whereas ANI exhibit high Ic value and *Rhizophora* species constitutes the important tree species. The low IC value indicating the low structural development and prevalence of disturbances in these mangrove stands.

Further abundance of *Avicennia* species indicates the prevalence of high saline condition in Indian mangrove habitat. Thus, despite the high species richness, species of low saline tolerant have restricted distribution. Abundances may decline long before the species richness does and so the species of low abundance should be given high conservation priority. Furthermore, mono-specific stands may have low thresholds for perturbations and be thus more vulnerable to environmental changes e.g. attack by diseases, drought, sedimentation, and flooding, among the stresses.

In recent times it has been understood that mangrove associated fauna play such a significant role to shape the mangrove forest structure and the functioning of the ecosystem [45-49]. Sediments, root structures and large woody debris are the three main substrata that fauna are able to exploit in mangroves [45,50-53]. The faunal communities in mangroves chiefly consists of terrestrial (insects, birds, mammals and reptiles), aquatic (fish, crustaceans, molluscs and echinoderms) and benthic animals (polychaetes, brachyuran crabs, wood-boring animals, mud burrowing bivalves, gobiid fish, gastropods and some sessile bivalves, such as oysters, Modiolus spp. and barnacle crustaceans [54]. However, faunal assemblages of mangroves are significantly less studied and documented than the forests they inhabit.

Mangrove forest ecosystems in India support diverse groups of fauna comprising of 3091 species. This is perhaps the largest biodiversity record in world mangrove ecosystems [55]. Invertebrates are greater in number of species than vertebrates. The faunal species so far recorded were highest (2061) in the mangroves of the east coast, followed by 922 species in Andaman and Nicobar Islands and 727 species on the west coast. In recent times faunal diversity in different sites of Indian mangroves has been studied [56-62]. However, the knowledge on faunal assemblage in Indian mangroves is far from complete and it significances in shaping the forest structure and ecosystem functioning is not determined due to lack of consistent in quantitative data.

The population structure and distance over which gene flow occurs can inform management decisions regarding conservation and management of threatened ecosystems [63]. Since mangroves are at elevated risk understanding of genetic status and the degree of divergence among populations is a necessary for successfully preventing their extinction [64,65]. It was previously assumed that mangroves are genetically undifferentiated throughout its range due to long-distance oceanic dispersal of these propagules [66,67].

However, experimental studies and recent molecular studies showed that strong genetic differentiation between populations of many mangrove species – *Ceriops tagal* and *C. decandra* [68], *Lumnitzera racemosa* [69,70], *L. littorea* [71], *Rhizophora apiculata* [72], *Sonneratia caseolaris* [73] and *S. alba* [74]. Except few regional specific studies [75-82], population structure of Indian mangroves has not been studied much. Patterns of genetic affinity and differentiation are generally explained by the presence of barriers in the landscape matrix, which may delay or hamper dispersal, and by testing the isolation-by-distance (IBD) model. Recent studies indicate the role of ocean currents, geomorphology, and hydrology of the estuary and water surface currents in shaping the population structure of mangrove species [83-86]. Furthermore, recent studies shown the low genetic diversity in the wide spread mangroves species of the world [87]. So understanding of regional specific population structure is desired for better understanding of current distribution pattern of mangrove species and conservation measures.

Biodiversity and ecosystem functioning of mangroves is determined by species composition and forest structure [88,89]. Since species diversity and distribution and forest structure of mangroves are variable in different spatial scales (i.e., global, regional, estuarine and intertidal), the ecological and socioeconomic benefits offered by mangroves are also variable between the region. So without site specific knowledge, it is imprecise to quantify the economic value of mangroves on broad scale at global level. In the last three decade various efforts have been taken to restore the degraded mangroves. However, many efforts have been documented to result in big failures in achieving the desired level of mangrove restoration due to poor species selection. In India, most of the mangrove restoration programmes were intended only to increase the area coverage and most afforestation efforts have been carried out with Avicennia species, with low or high survival rates.

On the whole in India mangrove cover has witnessed increasing trend and the number of mangrove taxa has also increased slightly on documentation since the mid-1980s, but their populations have not been tracked along the same trajectory. In the past, the conservation programmers for mangroves have largely been conducted with the lack of comprehensive species-specific information and often aimed to increase the area. In terms of mangrove conservation, only mangrove areas were rehabilitated, wherein ecological and economical services could not be fully restored. Since mangroves are present in land-sea transition zone, their natural extension is limited by urban development in landward side and sea level rise in seaward side.

The primary threats to all mangrove species are habitat destruction and removal of mangrove areas for conversion to

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aquaculture, agriculture, urban and coastal development, and overexploitation. Further, reduction in freshwater, nutrient enrichment through sewage discharge and sea level rise also threatened the mangrove species particularly low saline tolerant species. It is also pertinent to rejuvenate the species under significant threat (e.g. *Sonneratia griffithii*, *Brownlowia tersa*), especially those requiring stringent environmental conditions, like low salinity to grow (e.g. *Heritiera fomes*, *Nypa fruticans* etc,). Considering the low species richness and low genetic diversity it is imperative to assess the site specific information of mangroves to prevent it extinction. The contemporary mangrove conservation regime also advocates "early detection and pre-emptive rehabilitation", for successful management. And to achieve this, location-specific and species-specific information on the mangrove stands are the prerequisites [90], without which world without mangroves [91] will be a distinct possibility in the 22nd century.

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