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A review of the mangrove floristics of India

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ABSTRACT: The species composition in the mangrove habitats of India is reviewed and discussed. The review shows that Indian mangroves consist of 46 true mangrove species belonging to 14 families and 22 genera, which includes 42 species and 4 natural hybrids. In other words, about 57% of the world's mangrove species are represented in India. The East coast has 40 mangrove species belonging to 14 families and 22 genera. The West coast has 27 species belonging to 11 families and 16 genera and the Andaman and Nicobar Islands (ANI) have 38 species belonging to 13 families and 19 genera. Among the 13 States/Union Territories having mangroves, diversity is highest in the ANI. Species namely *Rhizophora* × *lamarckii*, *Lumnitzera littorea*, *Sonneratia ovata*, *S. lanceolata*, *S.* × *urama* and *S.* × *gulngai* are restricted to ANI in India. In terms of mangrove diversity, India is the third richest country in the world (after Indonesia and Australia). However, a majority of the Indian mangrove habitats are now threatened by various factors such as reduction in freshwater flow, marine & coastal pollution, siltation, sedimentation and excessive salinity. Periodical floristic surveys are needed to monitor and preserve the rich mangrove plant diversity in India.

KEY WORDS: Floristics, India, Mangroves.

INTRODUCTION

Mangrove forests in India are found along the coastline of 9 States and 4 Union Territories (Fig. 1). The mangrove habitat of India is broadly classified into three namely, Deltaic (Eastern Coast Mangroves), Estuarine & Backwater (Western Coast Mangroves) and Insular mangroves (Andaman & Nicobar Islands) (Mandal and Naskar, 2008). Their overall cover is estimated to be 4740 km^2, of which about 58% is along the east coast (Bay of Bengal); 29% along the west coast (Arabian Sea) and the remaining 13% in the Andaman and Nicobar Islands (FSI, 2015). The mangrove cover is larger and more widespread on the east coast compared to the west coast because of its distinctive geo-morphological setting. These differences in mangrove cover can be attributed to two reasons: i) the east coast has large estuaries with deltas formed due to runoff and deposition of sediments, whereas the west coast has funnel-shaped estuaries with an absence of deltas; and ii) the east coast has gentle slopes with extensive flats for colonization by mangroves, whereas the west coast has steep slopes (Kathiresan, 2010). The mangroves of Andaman and Nicobar Islands (ANI) are probably the best developed in India in terms of their density and growth (Dagar *et al*., 1991; Mandal and Naskar, 2008). Their irregular and deeply indented coastline results in innumerable creeks, bays and estuaries which facilitate the development of rich, extensive and luxuriant growth of mangrove forests with a high degree of biodiversity.

Despite its ecological and economical values, in the last two decades global mangroves have witnessed annual loss of between 0.16 and 0.39% due to rapid coastal development (Hamilton and Casey, 2016). However, little is known about the effects of either widespread or localized mangrove area loss on individual mangrove species or populations due to a lack of information about the distribution of individual species (Polidoro *et al*., 2010). The species richness of mangroves in many geographical regions is decreasing with time as a result of the destruction of mangrove forests and exposure to various anthropogenic stresses (Hamilton and Snedaker, 1984). The past and present distribution of mangrove species on a global scale has been reviewed by several authors (e.g. Tomlinson, 1986; Ricklefs and Latham, 1993; Duke, 1992; Field, 1995; Duke *et al*., 1998; Ellison *et al*., 1999; Saenger, 2002; Wang *et al*., 2003; Spalding *et al*., 2010), but in India the actual number of species of mangroves that exists in different regions is not fully known due to scattered data, and lack of both comprehensive compilation and extensive field surveys (Kathiresan, 2010). Without the adequate knowledge of the exact species composition it will be difficult to identify and implement conservation priorities for the mangroves of India. The present study aims to revise the floristics and distribution of true mangrove species in India on the basis of extensive literature survey and species information collected by the authors.

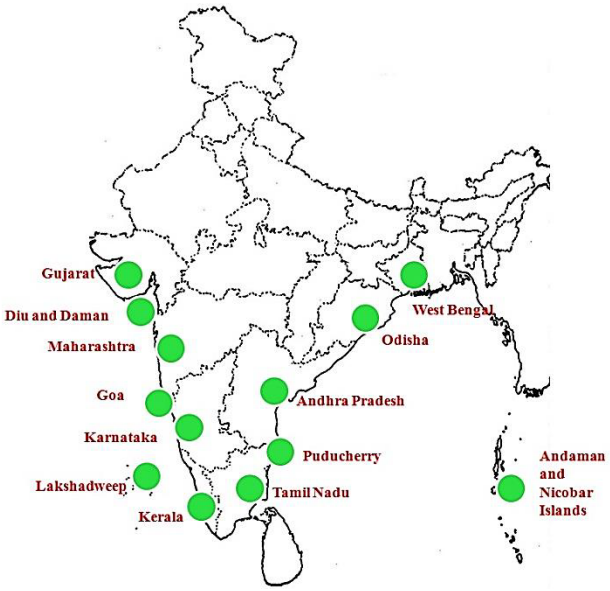

Fig. 1 Map showing mangrove habitats in India

Disparities in classification and composition of true mangrove species in India

Indian mangroves were extensively studied for its biogeography, ecology and forestry by many; however considerable disparities in species composition still exist, and there is lack of comprehensive locality data. For instance, Blasco (1977) reported 58 mangrove species in the Indian territories, while Rao (1986) listed 60 species from 41 genera and 29 families. Naskar and Guha Bakshi (1987) reported 35 true mangrove species, 28 mangrove associates and 7 back mangals. Untawale (1986), Banerjee *et al*. (1989), Deshmukh (1991) and the ENVIS Centre (2002) reported 59 species from 41 genera and 29 families. Jagtap *et al*. (1993) reported 50 mangrove species. Species *viz*., *Acrostichum* sp., *Acanthus* spp., *Pemphis acidula*, *Phoenix paludosa*, *Cynometra* spp., and *Dolichandrone spathacea* are globally considered as true mangrove species (Duke, 1992; Polidoro *et al*., 2010), whereas they are variably classified in India. Further, mere inclusion of associated littoral vegetation and of species occasionally present in mangroves and inclusion of species based on earlier reports also has contributed to erroneous additions to the mangrove flora of India, which emphasizes the importance of extending our knowledge of mangrove species diversity and distribution in India (Goutham-Bharathi *et al*., 2014)

Certain authors variably listed the true mangrove species of India (Table 1). For instance, Singh and Garge (1993) listed 32 mangrove species; Dagar *et al.* (1993) listed 36 mangrove species, while Naskar (2004), Selvam *et al.* (2002) and Kathiresan and Rajendran (2005) listed 43, 35 and 39 species respectively. In the recent past Mandal and Naskar (2008) and Sanjappa *et al*. (2011) attempted to review the mangrove flora of India, but their studies do not give a complete picture of the true mangrove species of India. Mandal and Naskar (2008) recognized a total of 82 mangrove species belonging to 52 genera and 36 families reported by various studies and made an attempt to classify them into major mangrove and mangrove associates based on modified morphological and anatomical characters of leaves, stems, roots, and reproductive organs. They listed 30 major mangrove species (true mangrove species) in India. The shortfalls of their results are species such as *Cynometra iripa*, *Excoecaria indica*, *Pemphis acidula* and *Acrostichum speciosum* were not included in their list and *Acanthus volubilis*, *Brownlowia tersa*, *Acrostichum aureum* and *Dolichandrone spathacea* were classified as mangrove associates. Similarly Anonymous (2008) and Kathiresan (2008) recognized 39 true mangrove species with the exclusion of *Acanthus volubilis*, *Aglaia cucullata* and *Phoenix paludosa* and they included *Cynometra ramiflora*, a species not considered as true mangrove species globally. Sanjappa *et al*. (2011) reported 68 true mangrove species, in their list coastal plants and salt marsh species *viz*., *Caesalpinia crista*, *Cerbera manghas*, *Clerodendrum inerme*, *Dalbergia spinosa*, *Thespesia populneoides* etc., were included as true mangroves. The adverse impact of including mangrove associates or beach vegetation and species unlikely to be present when reporting the total number of mangrove species in a given area has been discussed in detail by Jayatissa *et al*. (2002).

Definition and Classification of World mangrove species

The definition of a mangrove species is based on its habitat and morphological specialization (Tomlinson, 1986). Generally, mangroves are divided into two categories 'true mangrove species' (i.e. plants which are found only in tropical intertidal habitats) and 'mangrove associates' (i.e. plants which are not exclusive to these habitats; (Polidoro *et al*., 2010). However there is a great deal of uncertainty about the inclusion of certain species, such as, *Excoecaria agallocha*, *Heritiera littoralis*, *Acrostichum* spp., *Acanthus* spp., etc., in either of these two categories and opinion varies among the authors (Wang *et al*., 2010).

The practice of classifying mangrove species into true mangroves and mangrove associates was first used by Tansley and Fritsch (1905) in Sri Lanka. Since then, different approaches have been adopted in classifying the mangrove species, most often based on wide-ranging field observations of species zonation patterns (Duke, 1992; Lin, 1999; Smith, 1992) and the experience of observers but not on objective criteria (Lacerda *et al*., 2002). In the recent past Wang *et al*. (2010) attempted to classify mangroves more scientifically using leaf characters and the salt content of leaves, but the results did not remove uncertainty. Thus the classification of mangrove species into true mangroves and mangrove associates is not clear.

Table 1. List of true mangrove species reported by various authors in India. (• denotes occurrence.)

Species names	Singh & Garge (1993)	Dagar *et al*. (1993)	Naskar (2004)	Selvam *et al*. (2004)	Kathiresan & Rajendran (2005)	Mandal and Naskar (2008)	Kathiresan (2008)
Acanthus ebracteatus	•	•	•		•		•
A. ilicifolius	•	•	•	•	•	•	•
A. volubilis	•	•	•				
Acrostichum aureum				•	•		•
Ac. speciosum					•		•
Aegialitis rotundifolia	•	•	•	•	•	•	•
Aegiceras corniculatum	•	•	•	•	•	•	•
Aglaia cucullata			•	•	•		
Avicennia alba	•	•	•	•	•	•	•
Av. marina	•	•	•	•	•	•	•
Av. marina var. *acutissima*			•				
Av. officinalis	•	•	•	•	•	•	•
Atalantia correae			•				
Brownlowia tersa			•				
Bruguiera cylindrica	•	•	•	•	•	•	•
Br. gymnorrhiza	•	•	•	•	•	•	•
Br. parviflora	•	•	•	•	•	•	•
Br. sexangula	•	•	•	•	•	•	•
Ceriops decandra	•	•	•	•	•	•	•
C. tagal	•	•	•	•	•	•	•
Cynometra iripa		•	•	•			•
Cy. ramiflora		•	•				•
Dalbergia spinosa			•				
Dolichandrone spathacea					•		•
Excoecaria agallocha	•	•	•	•	•	•	•
E. indica					•		•
Heritiera fomes	•	•	•	•	•	•	•
H. littoralis	•	•	•	•	•	•	•
H. kanikensis				•	•		
Kandelia candel	•	•	•	•	•	•	•
Lumnitzera littorea	•	•	•		•	•	•
L. racemosa	•	•	•	•	•	•	•
Nypa fruticans	•	•	•	•	•	•	•
Pemphis acidula				•	•		•
Phoenix paludosa	•	•	•			•	
Rhizophora × *annamalayana*					•		•
R. apiculata	•	•	•	•	•	•	•
R. mucronata	•	•	•	•	•	•	•
R. × *lamarckii*	•	•	•	•	•		•
R. stylosa	•	•	•	•	•	•	•
Sarcolobus carinatus			•				
S. globosus			•				
Scyphiphora hydrophyllacea	•	•	•	•	•	•	•
Sonneratia alba	•	•	•	•	•	•	•
So. apetala	•	•	•	•	•	•	•
So. caseolaris		•	•	•	•	•	•
So. griffithii		•	•	•	•	•	•
Xylocarpus granatum	•	•	•	•	•	•	•
X. moluccensis	•	•	•	•	•		
X. mekongensis	•	•	•	•		•	•
Total number of species reported	32	36	43	35	39	30	39

To some extent the classification given by Tomlinson (1986) has been widely accepted (Parani *et al*., 1998; Kathiresan and Bingham, 2001; Lacerda *et al*., 2002; Saenger, 2002; Wang *et al*., 2003; Duke, 2006) and most taxa have been classified accordingly (Parani *et al*., 1998; Saenger, 2002). Tomlinson (1986) classified mangrove species into three categories *viz*., major mangrove components (true, strict, or specialized mangrove species), minor components (non-specialized mangrove species), and mangrove associates (species that are generally never immersed by high tides). He classified 34 species as major components and 20 species as minor components. However, Duke (1992) more specifically defined a true mangrove as "a tree, shrub, palm, or ground fern generally exceeding 0.5 m in height and which normally grows above mean sea level in the intertidal zone of tropical coastal or estuarine environments". He listed 69 true mangrove species worldwide. Recently Polidoro *et al*. (2010) defined a true mangrove species based on Tomlinson's

original list of major and minor mangroves (Tomlinson 1986), supplemented by a few species added through the expanded definition provided by Duke (1992) and other new taxonomic additions (Sheue *et al*., 2003; 2009). They listed 70 true mangrove species worldwide.

In order to provide a comprehensive list of true mangrove species in India, the present review considers species listed by Polidoro *et al.* (2010) as true mangrove species with the addition of *Ceriops pseudodecandra*, recently recognized as a new mangrove species by Sheue *et al.* (2010) and natural hybrids recognized by Duke (1992), Kathiresan (1995) and Ono *et al.* (2016). Polidoro *et al.* (2010) did not include natural hybrids of mangroves for the reason that IUCN Red List Guidelines generally exclude all plant hybrids for assessment unless they are apomicts. It is pertinent to note that Polidoro *et al.* (2010) classified *Bruguiera hainesii* as distinct species and categories as "critically endangered" but recently Ono *et al*. (2016) suggested that *Br. hainesii* is a putative hybrid between *Br. cylindrica* and *Br. gymnorrhiza*. So this taxon is treated here as hybrid species. On this basis the total number of true mangrove species in the world is 80, which includes 70 distinct species and 10 natural hybrids (see appendix). Old world mangroves have 69 species and new world mangroves have 12 species, of which only *Acrostichum aureum* is common to both the bioregions. Recently recognized hybrids *viz.*, *Rhizophora mucronata* × *Rhizophora stylosa* (Ng *et al.*, 2013; Ragavan *et al.* 2015b), *Sonneratia alba* × *Sonneratia griffithii* (Qiu *et al*., 2008), *Acrostichum aureum* × *Acrostichum speciosum* (Zhang *et al*., 2013, Ragavan *et al*., 2014c), *Rhizophora* × *tomlinsonii* (Duke, 2010) and *Avicennia marina* × *Avicennia rumphiana* (Huang *et al*., 2014) are not included in this total, because molecular evidence is lacking for *R.* × *tomlinsonii* and all other natural hybrids are unnamed. Moreover the distribution of these hybrids is not fully known.

Species diversity in mangrove habitats of India

Based on the definition of true mangrove species adopted in this study it was found that Indian mangroves represents 46 true mangrove species belonging to 14 families and 22 genera, which include 42 species and 4 natural hybrids. Area of mangrove cover and distribution of true mangrove species in mangrove habitats of India are given in Table 2 and Table 3 respectively.

Mangrove habitats of East coast

East coast has 40 mangrove species belonging to 14 families and 22 genera. In West Bengal, mangroves are present in the Sundarbans, the large deltaic complex of the river Ganges, shared by Bangladesh (62%) and India (38%). Totally 33 true mangrove species belonging to 21 genera and 14 families have been identified in Indian Sundarbans. The mangroves of the Odisha coast are distributed in three zones i.e. Mahanadi delta, Brahmani and Baitarani Delta, i.e., the Bhitarkanika mangrove zone and Balasore coast. Among these three mangrove zones, Bhitarkanika is the most important due to its largest stretch and unique biodiversity. Totally 35 true mangrove species belonging to 20 genera and 14 families have been recognized from mangroves of the Odisha. The mangrove forests of the Bhitarkanika Wildlife Sanctuary, the Mahanadi delta and Chilika Lake on Odisha coast have been studied extensively. However, attention has not been paid towards exploration of the mangrove vegetation of other estuaries like Devi, Budhabalanga, Rushikulya, Subarnarekha, etc., (Panda *et al*., 2013).

The mangrove forests in the Andhra Pradesh are located in the estuaries of the Godavari and the Krishna rivers, in East Godavari, Krishna and Guntur districts. Apart from these, mangroves are also found in small patches along the coast of Visakhapatnam, West Godavari and Prakasam districts. Swain *et al.* (2008) recently identified two mangrove habitats in Srikakulam districts, namely, Nuvvalarevu and Bhavanapadu. A total of 22 true mangrove species belonging to 15 genera and 11 families have been recognized in Andhra Pradesh. In Tamil Nadu mangroves are confined to Pichavaram, Muthupet and Gulf of Mannar. A total of 17 true mangrove species belonging to 12 genera and 8 families have been recognized from Tamil Nadu. Union territory of Puducherry consists of four regions *viz.*, Puducherry, Karaikal, Mahe and Yanam. Floral and faunal diversity of mangroves these regions have also been explored by Balachandran *et al.* (2009) and Saravanan *et al.* (2008). A total of 15 true mangrove species 10 genera and 7 families have been recognized in Union territory of Puducherry. Of the four regions, mangrove species diversity is rich in Yanam with 14 true mangrove species (Balachandran *et al.* 2009).

Table 2. State-wise changes in mangrove area cover (km^2) during the period 2003-2013 (As per India State of Forest Report, Forest Survey of India (2015); In Lakshadweep mangrove present only in small patches, so it not taken for assessment in FSI reports)

States/ Union Territories	2003	2005	2009	2011	2013	2015	Change with respect to 2013	Change with respect to 2003
Andhra Pradesh	329	354	353	352	352	367	15	38
Goa	16	16	17	22	22	26	4	10
Gujarat	916	991	1046	1058	1103	1107	4	191
Karnataka	3	3	3	3	3	3	0	0
Kerala	8	5	5	6	6	9	3	1
Maharashtra	158	186	186	186	186	222	36	64
Odisha	203	217	221	222	213	231	18	28
Tamil Nadu	35	36	39	39	39	47	8	12
West Bengal	2120	2136	2152	2155	2097	2106	9	-14
Andaman and Nicobar Is.	658	635	615	617	604	617	13	-41
Daman & Diu	1	1	1	1.56	1	3	1	2
Puducherry	1	1	1	1	1.63	2	1	1
Total	**4448**	**4581**	**4639**	**4663**	**4628**	**4740**	**112**	**292**

Table 3. Distribution of true mangrove species in mangrove habitat of India.

Species	WB	OD	AP	TN	PC	KR	GA	GU	KL	MA	LA	DD	ANI	Global status	Status in India
Acanthaceae															
Acanthus ebracteatus Vahl					•				•?				•	LC	EN
Acanthus ilicifolius L.	•	•	•	•	•	•	•	•	•	•		•	•	LC	LR
Acanthus volubilis Wall.	•												•	LC	NA
Avicennia alba Blume	•	•	•		•	•	•	•	?	•			?	LC	LR
Avicennia marina (Forssk.) Vierh	•	•	•	•	•	•	•	•	•	•	?	•	•	LC	LR
Avicennia officinalis L.	•	•	•	•	•	•	•	•	•	•			•	LC	LR
Arecaceae															
Nypa fruticans (Thunb.) Wurmb	•	?							?				•	LC	EN
Phoenix paludosa Roxb.	•	•											•	NT	NA
Bignoniaceae															
Dolichandrone spathacea (L.f.) Baill. ex Schumann	•	•							•	•			•	LC	VU
Combretaceae															
Lumnitzera littorea (Jack.) Voigt													•	LC	EN
Lumnitzera racemosa Willd.	•	•	•	•	•	•	•	•	•	•			•	LC	LR
Euphorbiaceae															
Excoecaria agallocha L.	•	•	•	•	•	•	•	•	•	•			•	LC	LR
Excoecaria indica (Willd.) Muell.-Arg.	•	•							•				•	DD	EN
Fabaceae															
Cynometra iripa Kostel.	•	•								•			•	LC	VU
Lythraceae															
Pemphis acidula J.R. Forst.				•							•		•	LC	VU
Sonneratia alba Sm.		•	•			•	•		•	•			•	LC	VU
Sonneratia apetala Buch.-Ham.	•	•	•	•?	•		?	•	?	•		•	?	LC	VU
Sonneratia caseolaris (L.) Engl.	•	•				•	•		•	•			•	LC	VU
Sonneratia griffithii Kurz.	•	•?											•	CR	EN
Sonneratia lanceolata Blume													•	LC	NA
Sonneratia × *urama* N.C. Duke.													•	NA	NA
Sonneratia × *gulngai* N.C. Duke													•	NA	NA
Sonneratia ovata Backer													•	NT	NA
Malvaceae															
Brownlowia tersa (L.) Kosterm.	•	•	•										•	NT	NA
Heritiera fomes Buch.-Ham	•	•												EN	VU
Heritiera littoralis Dryand.		•							?	•			•	LC	VU
Meliaceae															
Aglaia cucullata (Roxb.) Pellegr.	•	•											?	DD	NA
Xylocarpus granatum J. Koenig	•	•	•	•?			?			•			•	LC	VU
Xylocarpus moluccensis (Lam.) M. Roem.	•	•	•	•	•								•	LC	VU
Myrsinaceae															
Aegiceras corniculatum (L.) Blanco	•	•	•	•	•	•	•	•	•	•		•	•	LC	LR
Plumbaginaceae															
Aegialitis rotundifolia Roxb.	•	•	•										?	NT	VU
Pteridaceae															
Acrostichum aureum L.	•	•	•	•?		•	•		•	•			•	LC	LR
Acrostichum speciosum Willd.		•											•	LC	EN
Rhizophoraceae															
Bruguiera cylindrica (L.) Blume	•	•	•	•	•	•	•	•	•	•	•		•	LC	LR
Bruguiera gymnorrhiza (L.) Lam.	•	•	•		•	•	•	•	•	•			•	LC	LR
Bruguiera parviflora Wight & Arn. ex Griff	•	•							?	•	?		•	LC	VU
Bruguiera sexangula (Lour.) Poir.	•	•							•				?	LC	VU
Ceriops decandra (Griff.) Ding Hou	•	•	•	•		•		•					?	NT	VU
Ceriops tagal (Perr.) C. B. Rob.	•	•	•	•	•		•	•	•	•	•		•	LC	VU
Kandelia candel (L.) Druce	•	•	•			•	•	•	•	•			?	LC	LR
Rhizophora apiculata Blume	•	•	•	•	•	•	•	•?	•	•			•	LC	LR
Rhizophora mucronata Lam.	•	•	•	•	•	•	•	•	•	•			•	LC	LR
Rhizophora stylosa Griff.		•											•	LC	EN
Rhizophora × *annamalayana* Kathiresan				•									•	NA	EN
Rhizophora × *lamarckii* Montrouz													•	NA	EN
Rubiaceae															
Scyphiphora hydrophylacea C.F. Gaertn	•	•	•										•	LC	EN
Species	**33**	**35**	**22**	**17**	**15**	**16**	**16**	**15**	**19**	**22**	**3**	**4**	**38**		
Genera	**20**	**20**	**15**	**12**	**10**	**11**	**11**	**10**	**12**	**15**	**3**	**4**	**19**		
Family	**14**	**14**	**11**	**8**	**7**	**7**	**7**	**6**	**8**	**11**	**2**	**3**	**13**		

Global status as per Polidoro *et al.* (2010); Status in India as per Kathiresan (2008); WB: West Bengal: OD: Odisha, AP: Andhra Pradesh, TN: Tamil Nadu, PC: Puducherry, KR: Karnataka, GA: Goa, GU: Gujarat, KL: Kerala, MA: Maharashtra, LA: Lakshadweep, DU: Daman & Diu, ANI: Andaman and Nicobar Islands; CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern, DD: Data Deficient, VU: Vulnerable, LR: Lower risk, NA: Not assessed; • denotes occurrence; •? denotes occurrence not found in recent times; ? denotes occurrence not confirmed.

Puducherry, the largest of all the four, represents 9 species and mangroves are present in three villages namely, Ariankuppam, Murungapakkam, Veerampattinam and two islets-Thengaithittu and Ashramthittu (Saravanan *et al.* 2008).

Mangrove habitats of West Coast

West coast has 27 species belonging to 11 families and 16 genera. In Gujarat mangroves are present in the Indus deltaic region (Kachchh) i.e., Kori creek and Sir Creek area, Gulf of Kachchh, South Gujarat and Gulf of Khambhat. A total of 15 species belonging to 10 genera and 6 families have been recognized as true mangrove species of Gujarat. Area wise mangroves of Gujarat stand in second position in India, but there is less diversity compared to other habitats. Recently Bhatt *et al*. (2009) reported the occurrence of seven mangrove species in Purna estuary, South Gujarat, which makes it one of the most diverse mangrove patches in the State.

Mangrove patches of Kerala are mainly distributed in intertidal areas of Kochi, Vembanad, Kollam, Thiruvananthapuram, Kannur, Kozhikode and Kottayam. A total of 19 species belonging to 12 genera and 8 families have been recognized as true mangroves in Kerala. Five true mangrove species (*viz*., *Bruguiera parviflora, Sonneratia apetala, Avicennia alba, Heritiera littoralis* and *Nypa fruticans*) reported from Kerala by Mohandas *et al*. (2014) are treated as doubtful species in this text as they were not provided the voucher specimens details and taxonomical descriptions. The mangroves of Karnataka are confined to Uttar Kannada and Dakshina Kannada. The important estuarine areas where mangroves are present in Dakshina Kannada are Netravathi-Gurupur, Mulki-Pavanje, Udayavara-Pangala, Swarna-Sita-Kodi, Chakra-Haladi-Kollur, Baindur hole and Shiroor hole while in Uttarakannda the mangroves are present in the Honovar, Venkatapur, Sharavathi, Aghanashini, Gangavali and Kali river estuarine complexes. Totally 16 species belonging to 11 genera and 7 families have been recognized as true mangrove species in Karnataka. *Bruguiera cylindrica*, *Lumnitzera racemosa* and *Acrostichum aureum* were recently recorded by Nayak and Andrade (2008) from Karnataka.

In Maharashtra mangroves are spreading along the tidal river creeks and backwaters of Achara, Deogadh, Vijaydurg, Ratnagiri, Kundalica and Mumbradiva of the Mumbai region. Others include Veldur, Vikroli, Shreevardhan, Vaitarna, Vasai-Manori and Malvan. A total of 22 species belonging to 15 genera and 11 families have been recognized as true mangrove species in Maharashtra. Bhosale *et al*. (2002) reported the occurrence of *Xylocarpus granatum, Dolichandrone spathacea* and *Cynometra iripa.* Shaikh *et al*. (2011) and Chavan (2013) reported the presence of *Heritiera littoralis* and *Bruguiera parviflora* from Maharashtra respectively. In Goa mangroves are present in Mandovi estuary, Zuari estuary and Cumbarjua Canal. In addition, other parts of Galgibag, Talpona, Sal, Chapora and Terekhol river mouths also are endowed with mangrove vegetation. Goa has 16 true mangrove species belonging to 11 genera and 7 families. Mandovi River is one of the best developed mangrove forests and houses most of the species found in Goa (Sanjappa *et al*., 2011).

The Lakshadweep comprises of 36 islands and mangroves are known only from Minicoy Island. The species composition of mangroves of Minicoy Island is most disputed. For instance, Untawale and Jagtap (1984) and Naskar and Mandal (1999) noted occurrence of only *B. parviflora* from Minicoy Island, whereas Radhakrishnan *et al*. (1998) and Nasser *et al*. (1999) have reported *Bruguiera cylindrica*, *Ceriops tagal* and single solitary tree of *Avicennia marina* from Minicoy Island. In contrast Mandal and Naskar (2008) listed 8 species (*Avicennia marina, Lumnitzera racemosa, Rhizophora mucronata, Bruguiera gymnorrhiza, Br. cylindrica, Br. parviflora, Ceriops tagal and C. decandra*) belonging to 5 genera and 3 families from Lakshadweep. However, based on recent floristics survey (unpublished data) it was found that mangroves of Minicoy Island consist of three true mangrove species *viz.*, *Bruguiera cylindrica*, *Ceriops tagal* and *Pemphis acidula*. Of these homogenous patch of *Br. cylindrica* was observed in the south eastern side, whereas mixed strand of *Ceriops tagal* and *Pemphis acidula* was present in the south western sided. In addition, *Pemphis acidula* was also observed along entire coastal length of Minicoy Island. Since Lakshadweep Islands are coral atolls, the sediments often consist of coral deposits which favour the growth of *Pemphis acidula*. The single solitary tree of *A. marina* reported by Nasser *et al.* (1999) has not been found in the recent survey. In Diu & Daman mangroves are present on the banks of Chasi river estuary and four mangrove species *viz.*, *Avicennia marina*, *Acanthus ilicifolius, Aegiceras corniculatum* and *Sonneratia apetala* have been recorded from there (Sharma and Sikarvar, 2014).

Mangroves of Andaman and Nicobar Islands

It was found from this study that among the 13 States/Union Territories, mangroves of the Andaman and Nicobar Islands are the most diverse in its species composition than the other mangrove habitats in India with 38 species belonging to 13 families and 19 genera. Andaman Islands have 35 and Nicobar Island has 21 true mangrove species (Ragavan *et al*., 2015d). It is important to note that recent floristics studies (Ragavan *et al*., 2014b; Goutham-Bharathi *et al*., 2014; Ragavan *et al*., 2015d) contributed high species diversity in the ANI.

Distributional status of true mangrove species in India

Analysis of distribution of the true mangrove species in India shows that among the 46 mangrove species, 24 species have restricted distribution (Table 3). Among them 9 species are globally important in terms of their

conservation importance (IUCN, 2011). While *Sonneratia griffithii* and *Heritiera fomes* are critically endangered, *Excoecaria indica* and *Aglaia cucullata* are data deficient, and the remaining five species, viz. *Aegialitis rotundifolia, Brownlowia tersa, Ceriops decandra, Phoenix paludosa* and *Sonneratia ovata* are near threatened (Fig. 2). The 46 true mangrove species listed in this study include 38 species recognized by Kathiresan (2008) for status assessment in India as per IUCN criteria. The distribution status of the individual species is elaborated below.

Acanthaceae

Acanthaceae is represented by two genera *viz*., *Acanthus* and *Avicennia* in mangroves. The genus *Acanthus* is represented by three species in India *viz*., *Acanthus ilicifolius*, *A. ebracteatus* and *A. volubilis.* Of these, *A. ilicifolius* is commonly distributed, while *A. ebracteatus* is found only in Kerala, Puducherry and ANI at confined locations. Recently Saravanan *et al*. (2008) reported *A. ebracteatus* from Puducherry, but in recent times it is not reported from Kerala (Vidyasagaran and Madhusoodanan, 2014). In ANI it is reported only from South Andaman Island (Ragavan *et al*., 2015g). *A. volubilis* regarded as extinct, has been recently rediscovered in a confined location from Sundarbans (Mandal and Naskar, 2008) and Andaman Islands (Ragavan *et al*., 2014g). Recently Debnath *et al*. (2013) reported a new mangrove species *Acanthus albus* from Sundarbans. This new species is similar to *A. ilicifolius* except in flower colour and smaller size of leaves, fruits and flowers. Similar kind of specimen was reported from Sri Lanka by Liyanage (1997) as *A. volubilis*, and later it was confirmed as whitish flowered form of *A. ilicifolius* (Jayatissa *et al*., 2002). So the species status of *A. albus* needs to be checked and it is not included in this text.

The genus *Avicennia* is represented by three species *viz.*, *Avicennia alba*, *Av. marina*, and *Av. officinalis* and all are common in mangrove habitats of India. However the occurrence *Av. alba* in the ANI needs to be confirmed (Ragavan *et al*., 2014b; Goutham-Bharathi *et al*., 2014). In West coast of India also ecological varieties of *Av. marina* often misidentified as *Av. alba*. Thus the taxonomical identity and distribution of *Av. alba* and varieties of *Av. marina* need to be studied exclusively.

Arecaceae

Arecaceae is represented by two species *viz*., *Nypa fruticans* and *Phoenix Paludosa* in mangroves. In India both are known from Sundarbans and ANI. *Phoenix paludosa* is also reported from Odisha in a confined location (Mandal and Naskar, 2008). Pattnaik *et al*. (2008) have mentioned that due to over exploitation *Nypa fruticans* has become rare in Bhitarkanika, Odisha. In ANI *Nypa fruticans* is reported from Andaman Islands and Great Nicobar Island, whereas *Phoenix paludosa* is common in Andaman Islands (Ragavan *et al*., 2015d). *Nypa fruticans* and *Phoenix paludosa* are declining rapidly due to the reduction of freshwater input in the Sundarbans (Gopal and Chauhan, 2006; Bhutt and Kathiresan, 2011; Barik and Choudhury, 2014; Joshi and Ghosh, 2014). It is pertinent note that Mohandas *et al.* (2014) and Lovly and Teresa (2016) reported the occurrence of *Nypa fruticans* in Kerala coast. Though the photographs have been provided by them, the information of voucher specimens and taxonomical description has not been given. It pertinent to note that *N. fruticans* was listed from Malabar Coast by Van Rheede 1678-1693) in his classical work "Hortus Indicus Malabaricaus". So the presence of *N. fruticans* in Kerala to be validate through exclusive surveys.

Bignoniaceae

Bignoniaceae is represented by two genera *viz*., *Dolichandrone* and *Tabebuia* in mangrove communities. Of these the former is represented by one species *viz.*, *Dolichandrone spathacea,* found commonly in east and west coast of mainland India and ANI.

Combretaceae

Two species *viz*., *Lumnitzera littorea* and *L. racemosa* representing Combretaceae are recorded from India. *L. racemosa* is commonly distributed, while *L. littorea* is found only in the ANI.

Euphorbiaceae

Two species *viz*., *Excoecaria agallocha* and *E. indica* representing Euphorbiaceae are recorded in Indian mangroves. *E. agallocha* is commonly distributed, whereas *E. indica* is found in Sundarbans, Odisha and Kerala, but recently Ragavan *et al*. (2015a) reported *E. indica* from the ANI. It is pertinent to note that *E. indica* was often classified as associated flora under the nomenclature of *Sapium indicum*.

Fabaceae

Fabaceae is represented by two genera *viz*., *Cynometra* and *Mora* in mangrove communities. Of these former is represented by one species *viz*., *Cy. iripa* in mangrove communities. However, in India *Cy. iripa* and *Cy. ramiflora* are often classified as true mangrove species in India (Naskar 2004; Kathiresan 2008; Anonymous 2008; Sanjappa *et al.* 2011), but only *Cy. iripa* is the most common representative in mangroves swamps (Knaap-van Meeuwen 1970) and classified as a true mangrove species globally (Duke 1992; Polidoro *et al.* 2010) whereas *Cy. ramiflora* is found commonly in the fringes of the fresh water stream or back mangroves and also found inland. *Cynometra iripa* is known from Sundarbans, Odisha, Maharashtra and ANI, whereas *Cy. ramiflora* known only from ANI (Sanjappa 1992). Bhosale *et al.* (2002) reported the occurrence of *Cy. iripa* from Maharashtra. Earlier *Cy. iripa* was reported as rare in the ANI (Dagar *et al*. 1991) but recent studies revealed the common distribution of *Cy. iripa* in mangroves Andaman Islands (Ragavan *et al*. 2014a; Ragavan *et al.* 2015d).

Lythraceae

Two genera *viz*., *Pemphis* and *Sonneratia*

representing Lythraceae are found in Indian mangroves. The genus *Pemphis* is represented by one species *viz*., *Pemphis acidula* in mangroves, reported from Tamil Nadu and ANI. In ANI it is recorded from confined locations in Havelock, Neil, South Andaman and North Andaman Island (Ragavan *et al*., 2015d); in Tamil Nadu also its distribution is restricted to Mandapam area (Bhatt and Kathiresan, 2011). Recently Goutham-Bharathi *et al*. (2015) reported *P. acidula* from Havelock Island and it was noted that "reported after the lapse of 90 years" from the ANI, but earlier Ragavan *et al*. (2014a, b) had reported *Pemphis acidula* from Havelock Island and Corbyn's Cove with short notes and photographs. In Tamil Nadu Nedumaran (2016) documented the extended distribution of *P. acidula* from Palk Bay, South Eastern Coast-India. *Pemphis acidula* has not been recorded from west coast of mainland India. However, Gamble (1915-1935) reported *Pemphis acidula*, from the coasts of Malabar, Travancore and Tinnelvelly (Tirunelveli) in Flora of Presidency of Madras.

In India the genus *Sonneratia* is represented by seven species *viz*., *Sonneratia alba*, *So. caseolaris*, *So. griffithii*, *So. ovata*, *So. lanceolata*, *So.* × *urama* and *So.* × *gulngai*. Of these *So. ovata*, *So. lanceolata*, *So.* × *urama* and *So.* × *gulngai* are new records for India from the ANI (Dam Roy *et al*., 2009; Goutham-Bharathi *et al*., 2012; Nehru and Balasubramanian, 2012; Ragavan *et al*., 2014d), and not known from mainland India. *So. alba*, *So. apetala and So. caseolaris* are commonly distributed in Indian mangroves. However, the occurrence of *So. apetala* is doubted in Tamil Nadu (Arunprasath and Gomathinayagam, 2014), Goa (Kothari and Rao, 2002) and ANI (Ragavan *et al*., 2014a; Goutham Bharathi *et al*., 2014). *So. griffithii* is known from Sundarbans, Odisha and ANI. In Odisha *So. griffithii* is reported from Mahanadi delta (Kathiresan, 2010), but in recent times no reports are available. Recently Barik and Choudhury (2014) reported *So. griffithii* from Sundarbans and Ragavan *et al*. (2013) noted the distribution and status of *So. griffithii* in the Andaman Islands after a lapse of 90 years.

Meliaceae

Meliaceae is represented by two genera viz., *Xylocarpus* and *Aglaia* in mangroves. The genus *Xylocarpus* is represented by three species *viz*., *X. granatum*, *X. moluccensis* and *X. rumphii* in India. Of these *Xylocarpus granatum* and *X. moluccensis* are true mangrove species, whereas *X. rumphii* is a non-mangrove species. Recently Ragavan *et al*. (2015e) provided the taxonomical identity of three *Xylocarpus* spp. in the ANI and critically discussed the ambiguity in the nomenclature *viz*., *X. mekongensis* and *X. gangeticus* in Indian literature. In earlier references in India, *X. moluccensis* was regarded as *X. rumphii*, a non-mangrove species, and *X. mekongensis* and *X. gangeticus* were regarded as *X. moluccensis*, a taxon with prominent pneumatophores and bark with thick peelings (Ragavan *et al*., 2015e). In India,

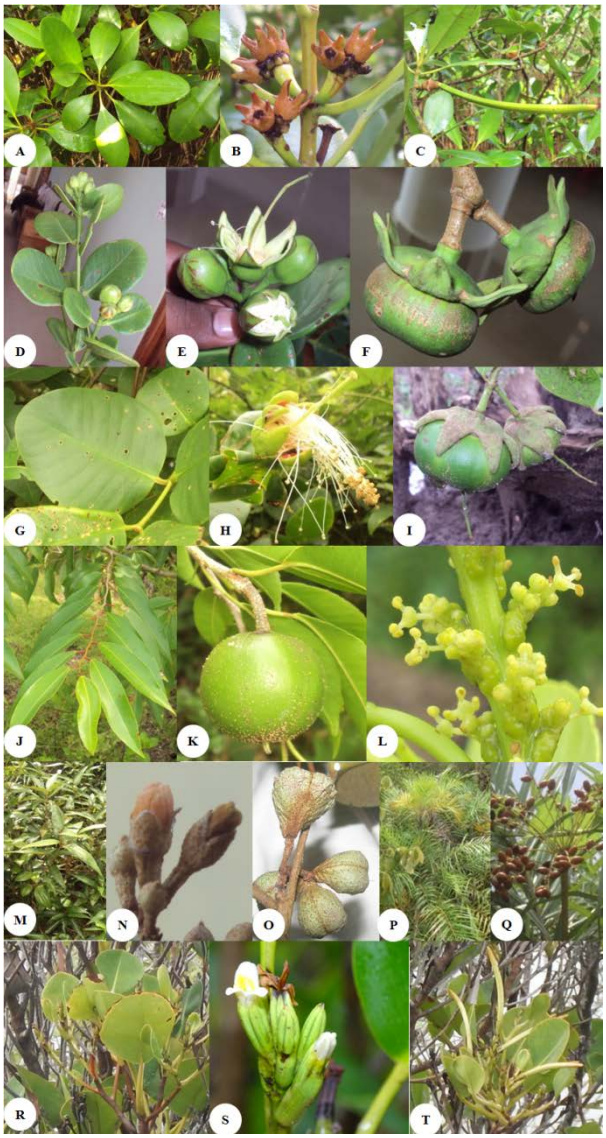

Fig. 2. Threatened true mangrove species of India (except *Heritiera fomes* and *Aglaia cucullata*). Leaves, flowers and fruits of *Ceriops decandra* **(A-C)**, *Sonneratia griffithii* **(D-F)**, *Sonneratia ovata* **(G-I)**, *Excoecaria indica* **(J-L)**, *Brownlowia tersa* **(M-O)**, *Phoenix paludosa* **(P&Q)**, *Aegialitis rotundifolia* **(R-T)**.

all the three species are known to occur on the coast of Odisha (Banerjee and Rao, 1990) and ANI (Ragavan *et al*. 2015e), whereas two species (*X. granatum* and *X. moluccensis*) are reported from the Sundarbans (Banerjee *et al*., 1989), Tamil Nadu (Deshmukh, 1991) and Andhra Pradesh (Raju, 2003), and only one species (*X. granatum*)from Maharashtra (Bhosale, 2002). It is important to note that *X. granatum* has not been reported by Arunprasath and Gomathinayagam (2014) in Tamil Nadu and in Goa it was reported by Dagar and Singh (1999), but it could not be recollected in the survey made by Kothari and Rao (2002).

The genus *Aglaia* represented by one species *viz.*, *Aglaia cucullata* is known to occur in Sundarbans, Odisha

and ANI, but for more than two decades this species has not been observed in the ANI (Ragavan *et al*., 2014a). In recent times, *A. cuculata* is reported from Sundarbans and Odisha by Barik and Choudhury (2014) and Panda *et al*. (2013), respectively. In Odisha *Ag. cucullata* is reported only from Bhitarkanika Wildlife Sanctuary with very restricted distribution (Panda *et al*., 2013).

Malvaceae

Malvaceae is represented by two genera *viz*., *Brownlowia* and *Heritiera* in Indian mangroves. The genus *Brownlowia* has two species *viz*., *B. tersa* and *B. argentata* in mangrove communities. Only *B. tersa* is known from Sundarbans, Odisha, Andhra Pradesh and ANI in India. In Andhra Pradesh it is recently reported from Ramannapalem of East Godavari (Venu *et al*., 2006; Swain and Rama Rao, 2008). In recent times *Bro. tersa* has been reported by Barik and Choudhury (2014) and Panda *et al*. (2013) from Sundarbans and Odisha respectively. *B. tersa* has been reported from ANI after a lapse of 90 years by Ragavan *et al*. (2016).

Two species of genus *Heritiera viz*., *Heritiera fomes* and *H. littoralis* are known from Indian mangroves, of which the former is reported only from Sundarbans and Odisha, but due to the reduction in freshwater input in both the places it has become rare. *Heritiera littoralis* is known from Odisha, Maharashtra and ANI. In Odisha *H. littoralis* is reported only in Bhitarkanika Wildlife Sanctuary and shows very restricted distribution (Panda *et al*., 2013). In Maharashtra it is recently reported by Shaikh *et al.* (2011), with just nineteen individuals recorded. In ANI it is common in both the groups of Islands (Ragavan *et al*., 2015d). *Heritiera kanikensis* reported by Majumdar and Banerjee (1985) as a new mangrove species from the Bhitarkanika of Odisha is now confirmed to be *H. fomes*, and not a new one (Kathiresan, 2010). Mohandas *et al.* (2014) noted the occurrence of *H. littoralis* in Kerala coast with taxonomical description, so it occurrences in Kerala need to revaluate.

Myrsinaceae

Myrsinaceae is represented by two species *viz*., *Aegiceras corniculatum* and *Aeg. floridum* in the mangrove communities, of which only *Aeg. corniculatum* is commonly known from Indian mangroves.

Pteridaceae

Two species *viz*., *Acrostichum aureum* and *Ac. speciosum* representing Pteridaceae are found in Indian mangroves, of which *A. aureum* is common, while *Ac. speciosum* is known only from Odisha and ANI. Recently, Ragavan *et al*. (2014c) provided the detailed taxonomical distinction between *Ac. aureum* and *Ac. speciosum* with their putative hybrid from the ANI.

Plumbaginaceae

Plumbaginaceae is represented by two species *viz*., *Aegialitis rotundifolia* and *Ae. annulata* in mangrove communities, of which the former is reported known from Indian mangroves *viz.*, Sundarbans, Odisha, Andhra Pradesh and ANI. In ANI, the occurrence of *Ae. rotundifolia* was doubted by several authors (Parkinson, 1923; Singh and Garge, 1993) but Dagar (1987) reported its presence from the Islands after a lapse of 80 years; however in his subsequent publication (Dagar *et al*., 1991) it was noted as unobserved. Recent floristics survey also has not reported *Ae. rotundifolia* in the ANI (Ragavan *et al*., 2014a; Ragavan *et al*., 2015d)

Rhizophoraceae

Four genera *viz*., *Bruguiera*, *Ceriops*, *Kandelia* and *Rhizopora* representing Rhizophoraceae are found in Indian mangroves. Four species of genus *Bruguiera viz*., *Br. gymnorrhiza*, *Br. cylindrica*, *Br. parviflora* and *Br. sexangula* are reported from India. Of these, former two species are common distributed in Indian mangroves, while *Br. parviflora* is restricted to Sundarbans, Odisha, Maharashtra and ANI and *Br. sexangula* occurs in Sundarbans, Odisha and Kerala. *Bruguiera sexangula* also reported from ANI (Singh *et al.* 1997; Debnath 2004; Dam Roy *et al.* 2009), however recent studies (Ragavan *et al*. 2014a; Goutham-Bharathi *et al.* 2014)) have revealed that reports of *Br. sexangula* from ANI might be an erroneous identification of ecological variants of *Br. gymnorrhiza*.

Two species of *Ceriops viz*., *Ceriops tagal* and *C. decandra* are common in Indian mangroves. Both the species have been reported from ANI; however only the former is reported in the recent studies (Ragavan *et al.* (2014a, b; Goutham Bharathi *et al*. 2014).

The genus *Kandelia* is represented by two species *viz*. *K. candel* and *K. obovata* in mangrove communities, of which the former is known from both east and west coasts and ANI. However its distribution is more common in west coast than east coast, and found in plenty by Mandovi, Mapusa and Zuari rivers. Its occurrence in the ANI has previously been doubted by several authors (Parkinson, 1923; Mall *et al*., 1987; Singh and Garge, 1993), but Jagtap (1985) reported *K. candel* (= *K. rheedii*) from the Andaman Islands, but in his subsequent publication (Jagtap 1994) he noted that *K. candel* has completely disappeared from the Andaman Islands. Recently Krishna Rao and Ramasubramanian (2013) reported occurrences of *K. Candel* in Andhra Pradesh and Pandey *et al*. (2009) reported single tree of *K. candel* from Gujarat.

The genus *Rhizophora* is represented by five species *viz*., *R. apiculata*, *R. mucronata*, *R. stylosa*, *R.* × *lamarckii* and *R.* × *annamalayana* in Indian mangroves. Of these, *R. apiculata* and *R. mucronata* are commonly distributed, but in Gujarat *R. apiculata* has not been recorded for more than one decade (Pandey and Pandey, 2011). *Rhizophora stylosa* is known from Odisha and ANI. In Odisha *R. stylosa* is found in confined location, whereas in the ANI *R. stylosa* is recorded from Havelock, Neil, South Andaman and Car Nicobar Island (Ragavan *et al*., 2015d). *R.* × *annamalayana*, a putative hybrid

between *R. apiculata* and *R. mucronata*, is reported from Pichavaram (Tamil Nadu) and ANI. In ANI *R.* × *annamalayana* is reported from South Andaman, Middle Andaman, Mayabunder, Havelock and Carnicobar (Ragavan *et al*., 2015f). *R.* × *lamarckii* is known only from the ANI. Singh *et al*., (1987) first reported it from Havelock Island in the ANI; however no further collections are available (Debnath, 2004). After a lapse of two decades Ragavan *et al*. (2015d) reported *R.* × *lamarckii* from Havelock and Neil Island. Recently two new entities of *Rhizophora viz*., *R.* × *mohanii* (putative hybrid between *R. stylosa* and *R. mucronata*) and *R. mucronata* var. *alokii* have been reported from mangroves of the ANI (Ragavan *et al*., 2015 b, c). These two entities are not included in this text.

Rubiaceae

One species *viz*., *Scyphiphora hydrophyllacea* representing Rubiaceae is reported in Indian mangroves and it is known from Sundarbans, Odisha and Andhra Pradesh as rare species and in the ANI it is common in the Andaman Islands and not found in the Nicobar Islands (Ragavan *et al*., 2015d).

Similarity among the mangrove habitats of India

In the present study, species composition was used to distinguish the community structure by hierarchical clustering (Bray-Curtis similarity) using PRIMER v. 6 software (Clarke and Gorley, 2006). It can be observed in the dendrogram (Fig. 3) that mangrove habitats of Lakshadweep, Daman & Diu and Puducherry exhibit low similarity with the other mangrove habitats in India. This is can be attributed to the low species diversity and the existence of mangroves in confined locations in these areas. All the other mangrove habitats in India grouped under a major cluster, further subdivided into two clades where major mangrove habitats in the West coast, Tamil Nadu and Andhra Pradesh clustered together in one clade and mangrove habitats of ANI, Odisha and Sundarbans clustered together in another. This clearly indicates that distinct geo-morphological settings in east and west coasts could be a major dispersal barrier among the mangrove habitats of India. However, the close similarity between ANI and mangrove habitats of West Bengal and Odisha indicates the dispersal of propagules/seeds between the east coast of mainland India and ANI.

Comparison with countries having rich mangrove diversity

Countries such as Australia, Indonesia, Malaysia, Thailand, Philippines, Singapore, China and India are rich in mangrove species diversity. In order to highlight the richness of mangrove species in India, the mangrove species diversity in all of the above countries has been assessed based on the classification adopted in this study. The results suggest that India is the third richest country in the world next to Indonesia and Australia, followed by Malaysia, Thailand, Philippines, Singapore and China (Table 4). Based on Bray Curtis similarity, it was observed that Indian mangroves have significant similarity with those of Thailand and also have close similarity with other Southeast Asian countries such as Indonesia, Philippines, Malaysia and Singapore. This supports the view of South East Asian region as the centre of origin of mangrove speciation. Mangroves of Australia and China form separate clusters each and show less similarity with the mangrove habitats of other countries (Fig. 4) which might be due to their different geographical location.

Among the 8 countries discussed above, three species i.e., *Acanthus xiamenensis*, *Sonneratia* × *hainanensis* and *Kandelia obovata* are confined to China. *Avicennia integra*, *Lumnitzera* × *rosea*, *Rhizophora samoensis*, *Rhizophora* × *selala* and *Diospyros littorea* are confined to Australia. *Sonneratia apetala* and *Rhizophora* × *annamalayana* are present only in India, among the eight counties discussed in this text, but *Sonneratia apetala* occurs also in Sri Lanka, Bangladesh and Myanmar (Kathiresan and Rajendran, 2005) and *R.* × *annamalayana* is also known from Sri Lanka (Jayatissa *et al*., 2002) and Indonesia (Baba, 1994), but the taxonomical identity has not been described properly.

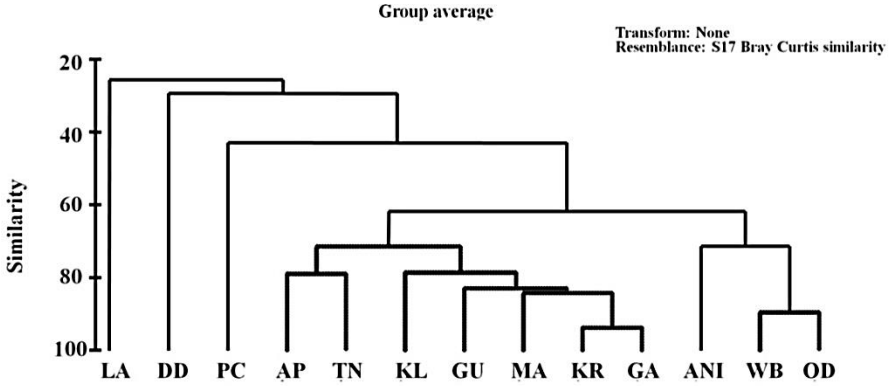

Fig. 3. Cluster dendrogram showing similarity among the Indian mangrove habitat.(WB-West Bengal. OD-Odisha, AP- Andhra Pradesh, TN-Tamil Nadu, PC- Puducherry, KR- Karnataka, GA- Goa, GU- Gujarat, KL- Kerala, MA- Maharashtra, LA-Lakshadweep, DD- Daman & Diu, ANI- Andaman and Nicobar Islands)

Table 4. Mangrove species composition in mangrove rich countries (• indicates presence)

Countries		Australia	India	Indonesia	Thailand	Malaysia	Singapore	China	Philippines
	Species	48	46	50	37	45	36	28	37
	Genera	21	22	22	20	22	18	16	19
	Families	16	14	14	13	13	12	11	12
Family	Species								
Acanthaceae	*Acanthus ebracteatus*	•	•	•	•	•	•	•	•
	Acanthus ilicifolius	•	•	•	•	•	•	•	•
	Acanthus volubilis		•	•	•	•	•		
	Acanthus xiamenensis							•	
	Avicennia alba	•	•	•	•	•	•		•
	Avicennia integra	•							
	Avicennia marina	•	•	•	•	•	•	•	•
	Avicennia officinalis	•	•	•	•	•	•		•
	Avicennia rumphiana	•		•		•	•		•
Arecaceae	*Nypa fruticans*	•	•	•	•	•	•	•	•
	Phoenix paludosa		•	•	•	•			
Bignoniaceae	*Dolichandrone spathacea*	•	•	•		•	•		
Combretaceae	*Lumnitzera littorea*	•	•	•	•	•	•	•	•
	Lumnitzera racemosa	•	•	•	•	•	•	•	•
	Lumnitzera × rosea	•							
Ebenaceae	*Diospyros littorea*	•							
Euphorbiaceae	*Excoecaria agallocha*	•	•	•	•	•	•	•	•
	Excoecaria indica		•	•		•	•		
Fabaceae	*Cynometra iripa*	•	•		•				
Lythraceae	*Pemphis acidula*	•	•	•	•	•	•	•	•
	Sonneratia alba	•	•	•	•	•	•	•	•
	Sonneratia apetala		•						
	Sonneratia caseolaris	•	•	•	•	•	•	•	•
	Sonneratia griffithii		•		•	•			
	Sonneratia lanceolata	•	•	•					
	Sonneratia ovata	•	•	•	•	•	•	•	•
	Sonneratia × gulngai	•	•	•				•	
	Sonneratia × urama	•	•	•					
	Sonneratia × hainanensis							•	
Malvaceae	*Brownlowia argentata*			•		•			•
	Brownlowia tersa		•	•	•	•	•		•
	Camptostemon philippinense			•					•
	Camptostemon schultzii	•		•					
	Heritiera fomes		•		•				
	Heritiera globosa			•		•			
	Heritiera littoralis	•	•	•	•	•	•	•	•
Meliaceae	*Aglaia cucullata*		•			•			
	Xylocarpus granatum	•	•	•	•	•	•	•	•
	Xylocarpus moluccensis	•	•	•	•	•	•		•
Myrsinaceae	*Aegiceras corniculatum*	•	•	•	•	•	•	•	•
	Aegiceras floridum			•		•			•
Myrtaceae	*Osbornia octodonta*	•		•		•			•
Plumbaginaceae	*Aegialitis rotundifolia*		•		•				
	Aegialitis annulata	•		•					
Pteridaceae	*Acrostichum aureum*	•	•	•	•	•	•	•	•
	Acrostichum speciosum		•	•	•	•	•	•	•
Rhizophoraceae	*Bruguiera cylindrica*	•	•	•	•	•	•	•	•
	Bruguiera exaristata	•		•					
	Bruguiera gymnorrhiza	•	•	•	•	•	•	•	•
	Bruguiera × hainesii	•		•	•	•	•		
	Bruguiera parviflora	•	•	•	•	•	•		•
	Bruguiera sexangula	•	•	•	•	•	•	•	•
	Bruguiera × rhynchopetala	•						•	
	Ceriops australis	•			•				
	Ceriops decandra	•	•	•	•	•			•
	Ceriops tagal	•	•	•		•	•	•	•
	Ceriops zippeliana					•	•		
	Ceriops pseudodecandra	•		•					
	Kandelia candel		•	•	•	•	•		•
	Kandelia obovata							•	
	Rhizophora apiculata	•	•	•	•	•	•	•	•
	Rhizophora mucronata	•	•	•	•	•	•		•
	Rhizophora samoensis	•							
	Rhizophora stylosa	•	•	•		•	•	•	•
	Rhizophora × annamalayana		•						
	Rhizophora × selala	•							
	Rhizophora × lamarckii	•	•	•		•			•
Rubiaceae	*Scyphiphora hydrophylacea*	•	•	•	•	•	•	•	•

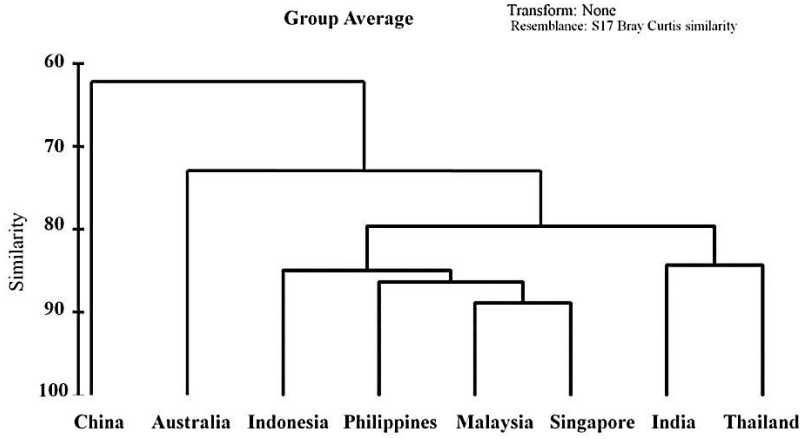

Fig. 4. Cluster dendrogram showing similarity among mangrove rich countries

Heritieria fomes and *Aegialitis rotundifolia* are present in India and Thailand. *Aglaia cucullata* is present in India and Malaysia. *Aegiceras floridum, Aegialitis annulata, Brownlowia argentata, Camptostemon schultzii, C. philippinense, Bruguiera exaristata, B. × rhynchopetala, Ceriops zippeliana, C. australis* and *C. pseudodecandra* are not reported from India but they are known from the few countries discussed. *Avicennia rumphiana* and *Osbornia octodonta* are known from Australia and South East Asian countries. It is important to note that recently *Brownlowia argentata* was confirmed as extinct in Singapore (Shufen *et al*., 2011).

Change in Mangrove floristics of India

According to recent estimate, mangrove cover of India has increased by 112 km^2 between 2013 and 2015 (FSI, 2015; Table 2). However, species diversity of Indian mangroves are under constant flux due to both natural (e.g. erosion, aggradation) and anthropogenic forces, possibly leading to changes in floristic composition and local extinction of some species. Recently Giri *et al.* (2008; 2014) and Hamilton and Casey (2016) also noted the implicit species loss despite mangrove expansion in Sundarbans and South East Asia respectively. In India except *Avicennia marina* and *Excoecaria agallocha*, all the other mangrove species are at varying degrees of threat (Kathiresan, 2008; Bhatt and Kathiresan, 2011). Such extinction risks are closely linked to direct or indirect human interventions.

Indian mangroves are not healthy and dense except, Sundarban, ANI and Maharashtra and are generally in a vulnerable condition (Kathiresan, 2010). The major factors which threatened species richness of Indian mangroves are deforestation for urbanization and Aquaculture and agriculture expansion, reduction in freshwater flow, marine and coastal pollution, siltation, sedimentation and excessive salinity. Deforestation and overexploitation of the mangrove resources have resulted in the formation of open marshy land of approximately 100,000 ha. The coastal areas like Gulf of Kutch (Gujarat), Mumbai (Maharashtra) and Cochin (Kerala) are the glaring examples of deforestation, reclamation, conversion and pollution due to population pressure (Kaladharan *et al*., 2005). Selvam (2003) mentioned that reduction in population density of *Heritiera fomes* in Sundarbans, of *Xylocarpus granatum*, *Sonneratia apetala*, *Kandelia candel* and *Bruguiera gymnorrhiza* in Pichavaram and of *Avicennia officinalis*, *Excoecaria agallocha* and *Luminitzera racemosa* in Godavari wetlands are attributable to reduction in the periodicity and quantity of freshwater reaching the mangrove environment. Experimental evidence also indicates that at high salinity, mangrove plants spend more energy to maintain water balance and ion concentration rather than for net production and growth (Bunt *et al*., 1982; Clough, 1984; Smith, 1989). Further, low frequency of tidal flooding also increases the salinity, resulting in poor germination, growth and regeneration of mangroves (Sahu *et al*., 2015). Hence, the increase in salinity due to reduction in freshwater flow and tidal inflow would lead to the disappearance of the low salinity tolerant species through a gradual decline of the population.

There are also indications of overexploitation leading to degradation and shrinkage of mangroves and the loss of certain species. For instance species of *Xylocarpus* and *Nypa fruticans* is becoming rare in Sundarbans and Odisha due to over-exploitation respectively (Naskar and Mandal, 1999; Pattnaik *et al*. 2008). Several recent habitat specific studies in the eastern coast reveal the conversion of mangrove areas by local communities for coastal agricultural land development and shrimp farming (Ambastha *et al*., 2010; Pattanaik and Narendra Prasad, 2011; Vyas and Sengupta, 2012). Recent remote sensing based evidences also reveal that conversion to aquaculture ponds still remains as a significant threat, especially to the mangroves along the eastern coast (Pattanaik and Narendra Prasad, 2011; Ponnambalam *et al*., 2012). In addition, increased population pressure poses a significant risk of unsustainable exploitation of mangroves (Mandal *et al*., 2010).

The tidal creeks and channels are conventionally used as drainage of large cities almost all over India (DasGupta and Shaw, 2008). Although mangroves are much more resistant to high levels of organic pollution, large quantity of waste has reportedly damaged the species diversity of mangroves. For example, *Sonneratia caseolaris*, once abundant in the Sundarbans is now almost extinct due to lack of regeneration in highly polluted lower-saline zones in Indian Sundarbans (Mandal *et al*., 2010). A good number of studies reveal that environmental pollution, especially the discharge of heavy metals and organic wastes, remains one of the most decisive factors for overall ecological health of mangroves almost all across India (Bhattacharya *et al*., 2003; Agoramoorthy *et al*., 2007; Remani *et al*., 2010; Bala Krishna Prasad, 2012).

It is believed that climate change would impact mangrove habitats worldwide apparently by an increasing sea level. The predicted Sea Level Rise (SLR) would result in the loss of 10 to 20% of global mangroves in the future (Gilman *et al*., 2007; 2008). The deltaic and the insular mangroves, especially the mangroves at the eastern coast like Sundarbans or Bhitarkanika are most likely to suffer the stress of sea level rise in the near future while the industrial and infrastructural development will continue to stress the western coast mangroves. Changing pattern and magnitude of cyclone, rainfall intensity and shoreline erosion also threatened species diversity of mangroves. However, natural phenomenon has a lesser threat to mangrove ecosystems than anthropogenic activity (Naskar and Mandal, 1999). Species diversity was decreased in many regions due to land use changes (Ramachandran *et al*., 2005). Current status indicates that, except in the Andaman and Nicobar Islands, in all the other mangrove wetlands of India, low saline-tolerant species are gradually disappearing and species like *A. marina* which can tolerate a high and broad range of salinity are becoming dominant.

Conservation and Management of mangroves of India

India has a long tradition of mangrove forest management. The Sundarbans mangroves, located in the Bay of Bengal (partly in India and partly in Bangladesh), were the first mangroves in the world to be put under scientific management. The area's first management plan was implemented in 1892 (Chaudhuri and Choudhury, 1994). Indian mangroves were very much a part of the vast forest resources of the country and were managed accordingly. It received a special distinction only after the Ramsar Convention (1971), followed by Convention concerning the Protection of the World Cultural and Natural Heritage (1972). Recognizing the importance of mangroves, the "National Mangrove Committee (NMC)" was formed in 1976 as an advisory body to the Government of India to promote conservation.The Committee, in its first recommendation in 1979, suggested for scientific assessment and evaluation of the mangrove habitats in the country. The committee further identified 15 sites for conservation of mangrove habitats during 1987. The goal of this scheme was to develop the degraded mangrove ecosystems, maintain and enrich the biological diversity in mangrove areas and create public awareness for protection of mangrove ecosystems at provincial level.

Presently, most of the Indian mangrove habitats enjoy the legislative protection under Indian Forest Act, 1927, various State Forest Acts, Forest (Conservation) Act, 1980 & the Wildlife (Protection) Act, 1972. Coastal Zoning is essentially important to conserve the mangroves and to restrict coastal urbanization and other developmental activities. For such purpose, the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India issued the Coastal Regulation Zone (CRZ) Notification (2011) under the Environmental Protection Act, 1986. Under the present coastal zone regulation, all the Indian mangroves are covered under the CRZ I as Ecologically Sensitive Area (ESA) and receives strong legal protection under the Environmental Protection Act, 1986. The Environmental Protection Act also regulates other activities that may adversely affect the sensitive ecosystems through the Environmental Impact Assessment Notification (EIA), 1994. Furthermore, Coastal Aquaculture Authority Act, 2005 is also considered a recent development with respect to the protection of mangroves.

In India mangrove restoration gained momentum during 1990's and the restoration strategy is adopted based on the tidal amplitude. Consequently, the entire coastal area is divided into two categories i.e., High tidal amplitude area (Gujarat and West Bengal), and Low tidal amplitude area (Mathew *et al*., 2010). In high amplitude area the existing planting technique of direct seed sowing and planting of seedlings in the mud flats are followed whereas in low amplitude areas (Tamil Nadu and Andhra Pradesh) "Canal Bank Planting' was used. This approach has been successfully demonstrated in mangrove forests at Pichavaram, Tamil Nadu, by MSSRF (MSSRF, 2002). The technique was first attempted in 1987 in mangrove forests at Muthupet, Tamil Nadu, and different models have since been developed (Baruah, 2004). 'Fish bone' design has been the most successful of all the canal bank planting designs tried so far, and it happens to be the latest improved design for the canal bank planting.

Recent increase in mangrove cover of India could be due to plantation and constant protection efforts measures taken by the each state forest department. For instance, the highest increase in the mangrove cover of Maharashtra (36 km^2) was attained as result of declaration of mangroves as reserved forests by Maharashtra state government. However, counter arguments were also presented regarding the inaccurate results of satellite mapping. Mangrove forests generally possess a high resilience to natural disturbances such as tropical storms and tsunamis. They have the tendency to self-repair or undergo successful secondary succession over the period

of 15-30 years provided there is suitable hydrology and seed sources from the adjacent intact forest are available mangroves (Bhatt and Kathiresan, 2012), and so it is possible that secondary succession of mangroves in tsunami affected areas could also have contributed to the recent increase in mangrove cover of India. It was also reported that the submerged areas in ANI are more conducive for colonization of mangroves (Das *et al*., 2014; Sachithanantham *et al*., 2014). By comparing the 2003 assessment it is evident that except ANI and Sundarban, in all other mangrove habitats witnessed as increasing trend in last decade (Table 2). In the ANI a total of 41 km^2 areas has decreased, this could be the consequences of 2004 catastrophic event and the recent increase of 13 km^2 indicates the high resilience potential of mangroves of the ANI. In case of Sundarbans only 14 km^2 have been decreased. Giri *et al*. (2011) and Ghosh *et al*. (2015) also reported that total mangrove area of Indian Sundarbans did not change significantly over the last few centuries. Further, it was reported that slight fluctuation in area cover of Indian Sundarbans would be the result of internal mangrove dynamics with small-scale land loss and gain by erosion and accretion of sediments within the tidal channels (Ghosh *et al*., 2015). Among the emerging nations with fast growing economies, India is giving great preference to research in mangrove ecosystem next to China (Beys-da-Silva *et al*., 2014). There are 38 mangrove areas in the country under active implementation of management action plan with 100% financial support by the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India (Kathiresan, 2010). In general, Indian mangroves are well protected in last two decades in spite of growing threats by climate change and anthropogenic impacts, mainly due to the efforts of Government of India.

CONCLUSION

Mangrove ecosystems are threatened globally due to various anthropogenic activities and global climate change. Mangrove is the only marginal ecosystem which shares the resources with adjoining ecosystems (Vannucci, 2001). Adverse effects on mangroves could lead to serious consequences for the adjoining fragile and important ecosystems such as coral reefs and sea grass beds. Damage to mangroves affects the sediment budget and promotes the coastal erosion. Moreover, the ecological and socioeconomic values offered by the mangroves are innumerable, immeasurable and incomparable. So conserving the mangroves should be a priority in any nation's conservation programs. The status and species composition of mangrove forest is a basic requirement and a pre-requisite for the management and conservation of mangrove resource. It is necessary to collate comprehensive species specific information for the mangroves of India, in the absence of which it will be difficult to set up conservation priorities (Kathiresan, 2010). Thus, the comprehensive information on diversity in mangroves of India provided here will help in the long term monitoring of mangrove species in the country and formulating species specific conservation strategies.

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Appendix: List of world true mangrove species.

Indo West Pacific mangrove species

Acanthaceae
1. *Acanthus ebracteatus* Vahl
2. *Acanthus ilicifolius* L.
3. *Acanthus volubilis* Wall.
4. *Acanthus xiamenensis* R.T. Zhang
5. *Avicennia alba* Blume
6. *Avicennia integra* N.C. Duke
7. *Avicennia marina* (Forssk.) Vierh.
8. *Avicennia officinalis* L.
9. *Avicennia rumphiana* Hallier f.

Arecaceae
10. *Nypa fruticans* (Thunb.) Wurmb
11. *Phoenix paludosa* Roxb.

Bignoniaceae
12. *Dolichandrone spathacea* (L.f.) Baill. ex Schumann

Combretaceae
13. *Lumnitzera littorea* (Jack.) Voigt
14. *Lumnitzera racemosa* Willd.
15. *Lumnitzera* × *rosea* (Gaudich.) C. Presl

Ebenaceae
16. *Diospyros littorea* Kosterm.

Euphorbiaceae
17. *Excoecaria agallocha* L.
18. *Excoecaria indica* (Willd.) Muell.-Arg.

Fabaceae
19. *Cynometra iripa* Kostel.

Lythraceae
20. *Pemphis acidula* J.R. Forst.
21. *Sonneratia alba* Sm.
22. *Sonneratia apetala* Buch.-Ham.
23. *Sonneratia caseolaris* (L.) Engl.
24. *Sonneratia griffithii* Kurz.
25. *Sonneratia lanceolata* Blume
26. *Sonneratia ovata* Backer
27. *Sonneratia* × *gulngai* N.C. Duke
28. *Sonneratia* × *urama* N.C. Duke
29. *Sonneratia* ×*hainanensis* Ko, E.Y. Chen & S.Y. Chen

Malvaceae
30. *Brownlowia argentata* Kurz.
31. *Brownlowia tersa* (L.) Kosterm.
32. *Camptostemon philippinense* (S. Vidal) Becc.
33. *Camptostemon schultzii* Mast.
34. *Heritiera fomes* Buch.-Ham.
35. *Heritiera globosa* Kosterm.
36. *Heritiera littoralis* Dryand.

Meliaceae
37. *Aglaia cucullata* (Roxb.) Pellegr.
38. *Xylocarpus granatum* J. Koenig
39. *Xylocarpus moluccensis* (Lam.) M. Roem.

Myrsinaceae
40. *Aegiceras corniculatum* (L.) Blanco
41. *Aegiceras floridum* Roem. & Schult.

Myrtaceae
42. *Osbornia octodonta* F. Muell.

Plumbaginaceae
43. *Aegialitis rotundifolia* Roxb.
44. *Aegialitis annulata* R. Br.

Pteridaceae
45. *Acrostichum aureum* L.
46. *Acrostichum danaeifolium* Langsd. & Fisch.
47. *Acrostichum speciosum* Willd.

Rhizophoraceae
48. *Bruguiera cylindrica* (L.) Blume
49. *Bruguiera exaristata* Ding Hou
50. *Bruguiera gymnorrhiza* (L.) Lam.
51. *Bruguiera* × *hainesii* C.G. Rogers
52. *Bruguiera parviflora* Wight & Arn. ex Griff
53. *Bruguiera sexangula* (Lour.) Poir.
54. *Bruguiera* × *rhynchopetala* (W.C.Ko) N.C.Duke & X.J.Ge
55. *Ceriops australis* (C.T. White) Ballment, T.J.Sm. & J.A. Stoddart
56. *Ceriops decandra* (Griff.) Ding Hou
57. *Ceriops tagal* (Perr.) C.B. Rob.
58. *Ceriops zippeliana* Blume
59. *Ceriops pseudodecandra* Sheue, Liu, Tsai, and Yang
60. *Kandelia candel* (L.) Druce
61. *Kandelia obovata* Sheue, H.Y. Liu & J. Yong
62. *Rhizophora apiculata* Blume
63. *Rhizophora mucronata* Lam.
64. *Rhizophora samoensis* (Hochr.) Salvoza
65. *Rhizophora stylosa* Griff.
66. *Rhizophora* × *annamalayana* Kathiresan
67. *Rhizophora* × *selala* (Salvoza) P.B.Tomlinson
68. *Rhizophora* × *lamarckii* Montrouz.

Rubiaceae
69. *Scyphiphora hydrophyllacea* C.F. Gaertn.

Atlantic East Pacific mangrove species

Acanthaceae
1. *Avicennia bicolor* Standl.
2. *Avicennia germinans* (L.)L.
3. *Avicennia schaueriana* Stapf & Leechm. ex Moldenke

Combretaceae
4. *Conocarpus erectus* L.
5. *Laguncularia racemosa* (L.) C.F. Gaertn.

Rhizophoraceae
6. *Rhizophora mangle* L.
7. *Rhizophora racemosa* G. Mey.
8. *Rhizophora* × *harrsonii* Leechm.

Bignoniaceae
9. *Tabebuia palustris* Hemsl.

Fabaceae
10. *Mora oleifera* (Triana ex Hemsl.) Ducke

Tetrameristaceae
11. *Pelliciera rhizophorae* Planch. & Triana

Pteridaceae
12. *Acrostichum aureum* L.

Hybrids recently identified

1. *Rhizophora mucronata* × *Rhizophora stylosa* (Ng *et al.* 2013 and Ragavan *et al.* 2015b)
2. *Sonneratia alba*× *Sonneratia griffithii* (Qiu *et al.* 2008)
3. *Acrostichum aureum* × *Acrostichum speciosum* (Zhang *et al.* 2013, Ragavan *et al.* 2014c)
4. *Rhizophora* × *tomlinsonii (Duke 2010)*
5. *Avicennia marina* × *Avicennia rumphiana* (Huang *et al.* 2014)