

Review article

Mangroves of Sri Lanka: Distribution, status and conservation requirements

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Abstract: Mangroves are a diverse group of highly salt-tolerant woody plants, which grow in the inter-tidal zones in tropical and subtropical latitudes. Despite its unique services to the people, coastal and marine systems, mangroves have become one of the most rapidly disappearing ecosystems in the world. This paper reviews the available information on distribution, current status and challenges of mangroves in Sri Lanka. Today, around 160 km² of mangrove vegetation is available in Sri Lanka and distributed mainly in Jaffna, Batticaloa, Kalpitiya, Rekawa and Trincomalee and is composed of 21 species of true mangroves and 24 species of mangrove associates. Mangroves in the island have been adversely affected due to the numerous anthropogenic activities, including land reclamation, tourism, coastal aquaculture and agriculture and other industrial activities *etc.* Proper conservations of mangroves are urgently required to the island to avoid further decline of mangrove ecosystem. It is imperative to evaluate policies, legal instruments and development strategies to effectively protect this valuable ecosystem.

Keywords: Challenges - Conservation - Current status - Protection of mangroves.

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INTRODUCTION

Mangroves are one of the most productive ecosystems in the world (Zvonareva *et al.* 2015). They may be either shrubs or small trees and primarily marginalize the intertidal zone along with sheltered coastal, estuarine and riverine areas in tropical and subtropical latitudes, and they also occur in coastal lagoons and the supra-littoral zone (Ashton 2008). Being living at the interface between land and sea, mangroves are highly adapted to cope with the harsh conditions, such as high salinity, extreme tides, strong winds, high temperatures, muddy and anaerobic soils (Kathiresan & Bingham 2001, Reef & Lovelock 2015, Wen *et al.* 2016). Mangroves are well recognized owing to its unique ecological functions, services and socio-economic values (Devi & Pathak 2016, Das *et al.* 2019). Mangrove forests provide protection and feeding and rearing habitats for many fish species, crustaceans, shellfish and hence support local and commercial fisheries (Alongi 2002, Boone & Bhomia 2017, Yaney-Keller *et al.* 2019).

Mangroves also provide a breeding ground for birds, reptiles and mammals (Alongi 2002, Walters *et al.* 2008). The ecosystem also plays an important role in purifying water and protection against salt intrusion, protection of nearby beaches and coral reefs, supplying nutrient resources, carbon sequestration and land stabilization (Gunawardena & Rowan 2005, Walters *et al.* 2008, Guannel *et al.* 2016, Weiss *et al.* 2016, Gao *et al.* 2019, Van der Stocken *et al.* 2019). Moreover, mangrove vegetation acts as a bio-shield, against high energy waves and storm surges during extreme weather conditions and hence protect the coastlines and human settlements (Das & Vincent 2009, Boone & Bhomia 2017, Walcker *et al.* 2019). Mangroves are also traditionally used by locals for food, timber, fuel and medicine (Alongi 2002). As reported by Hrudayanath *et al.* (2016), about 84 mangrove species belonging to 24 genera and 16 families, have been identified in the world. 11 mangroves have been categorized as threatened species by IUCN (International Union for Conservation of Nature) (Saddhe *et al.* 2016).

Sri Lanka is a small tropical island (about 65,610 km²), which lies in the Indian Ocean, a few kilometers away from the southeastern coast of India (Arulpragasam 2000, Geekiyanage *et al.* 2015). Being an island nation, Sri Lanka is enriched with beaches, sand bars and spits, estuaries, lagoons and bays, sand dunes and mangrove ecosystems (Nayananda 2007). Importance as well as attention of the mangrove ecosystem was gained more after Tsunami, which is hit Sri Lanka on 26th December 2004 and coastal strip (1,700 km long) of Sri Lanka was heavily destructed due to this tragedy, including the mangrove ecosystem (Nayananda 2007, Samarakoon & Samarawickrama 2012). According to Ranawana (2017), about 160.12 km² of mangrove forests can be found in the island. Most of the mangrove forest areas in the island have been subjected to human interference and therefore, undisturbed mangrove forests are rarely found (Gunawardena *et al.* 2016).

While moving to the global, it was estimated that about 152,000 km² of the global area (Nabeelah Bibi *et al.* 2019) is occupied by the mangroves and represented about 0.12% of the Earth's terrestrial surface (Moity *et al.* 2019). Mangroves can be found in 123 countries in the world (Mukherjee *et al.* 2014). Among them, Indonesia is the country, which is having the largest mangrove coverage in the world, representing 25.79% of the global total (Nabeelah Bibi *et al.* 2019). Apart from that, Brazil, Malaysia, Venezuela, Nigeria, Papua New Guinea, Colombia, Mexico, Thailand and Gabon are the top ranked countries based on the mangrove distribution area (Fig. 1).

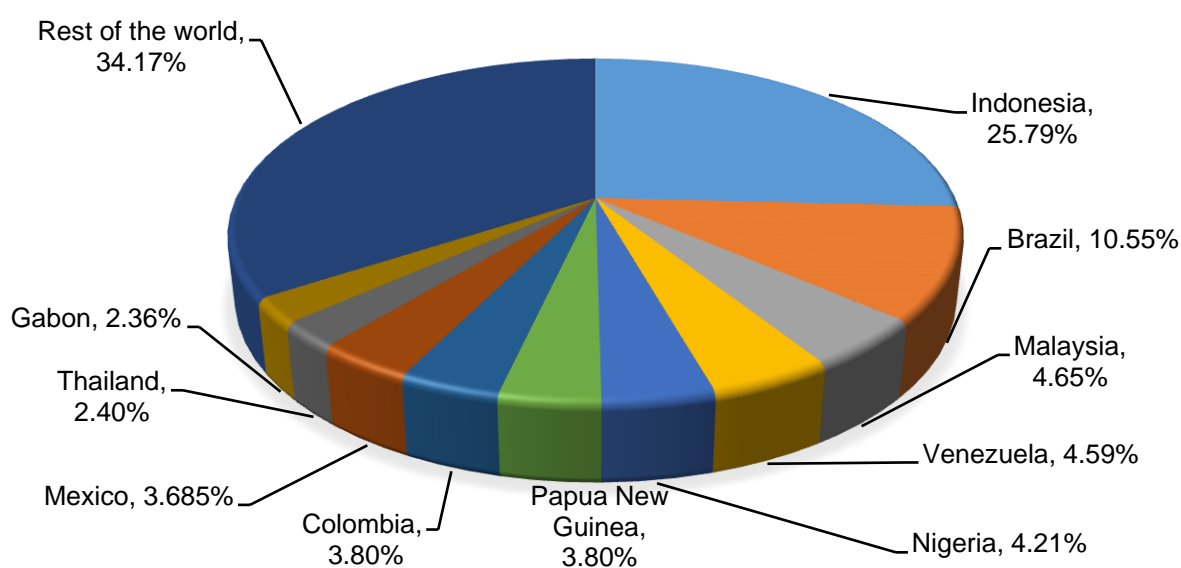


Figure 1. Global percentage of mangrove distribution: Indonesia, Brazil, Malaysia, Venezuela, Nigeria, Papua New Guinea, Colombia, Mexico, Thailand and Gabon are the top (10) ranked countries with 42278, 17287, 7616, 7516, 6908, 6236, 6236, 6036, 3936 and 3864 km² area coverage respectively. Mangrove percentage of those countries with respect to the global are 25.79, 10.55, 4.65 and 4.59 etc. respectively. [Source: Nabeelah Bibi *et al.* (2019)]

Because of its significance, mangroves are protected by the laws, rules and regulations in the world (Andrade *et al.* 2018). However, over the past century, a significant decline of mangrove coverage was observed throughout the world (Blankespoor *et al.* 2017, Menéndez *et al.* 2019). The most extensive losses have been recorded in Asia, followed by Africa, and North and Central America (Pham *et al.* 2019). It was estimated that during the past 50 years, approximately 30–50% of natural mangroves were destroyed in the world (Gao *et al.* 2019). During the 1980s, Indonesia, Mexico, Pakistan, Papua New Guinea and Panama recorded the largest losses of mangroves, which shared a loss of 0.01 million square kilometers (FAO 2007).

It is estimated that, about 0.036 million km² of mangrove vegetation have been lost in the world including Vietnam, Thailand, Philippines, Myanmar, Brazil, China, Malaysia, Bangladesh, and India (Paul & Vogl 2011, Asbridge *et al.* 2016, Ahmed *et al.* 2018). Furthermore, during 1980 to 2000, about 1.04% of average annual losses of mangrove forests were recorded. However, comparatively fewer annual losses (0.66%) were recorded from 2000 to 2005. The average loss rates between 2000 and 2012 may have stabilized or further declined (Blankespoor *et al.* 2017). It also predicted that the decline of mangrove forests will be at the current rate in the next couple of years, unless it is managed based on a sustainable strategy (Alongi 2002). Habitat destruction has been the primary cause of mangrove decline in the world (Kathiresan & Bingham 2001), where more than 50% of mangroves were lost between 1950 and 2000 in China due to habitat destruction (Wu *et al.* 2018). Anthropogenic activities are the prime cause for mangrove destruction rather than natural events and processes (Satyanarayana *et al.* 2012, Asbridge *et al.* 2018).

The most dominant threats from anthropogenic activities to the mangrove destructions are aquaculture practices, salt farming, tourism, urbanization and overexploitation of mangrove timber (Kathiresan & Bingham 2001, Adame *et al.* 2013, Blankespoor *et al.* 2017, Nehemia & Kochzius 2017). Mangrove dynamics are also affected by the intense storms, tsunami conditions, changes in freshwater run-off, salinity regime and tidal flow patterns, changing sea levels and excessive siltation (Katupotha 2001, Asbridge *et al.* 2018, Gandhi & Jones 2019). It is also identified that mangrove areas, which are located close to densely populated urban or rural settlements are often vulnerable to degradation (Satyanarayana *et al.* 2013). Mangrove losses in countries like Myanmar and Indonesia are at a fast rate. Annual mangrove loss rate in Indonesia is double compared with the global average (Hamilton & Casey 2016).

True mangroves and mangrove associates

Mangroves are classified into two as “true mangroves” or “obligate mangroves” and “mangrove associates” or “semi-mangroves” (Wang *et al.* 2011a, b). True mangroves habitat only in mangrove forests and are not found in terrestrial communities. They are also morphologically specialized to the mangrove environment and bear specialized morphological adaptations such as aerial roots, buttresses, salt-excretion through leaves, buoyant and viviparous propagules (Quadros *et al.* 2017). Mangrove associates may occur as transitional vegetation between true mangroves and the terrestrial vegetation, without featuring all the highly specific adaptations as developed in true mangroves (FAO 2007).

Species composition and distribution of mangroves in Sri Lanka

Since the tidal amplitude is very low (<1 m) in Sri Lanka, the distribution of mangrove forests are confined to a narrow strip (Bambaradeniya *et al.* 2002). The mangrove coverage of the island is only about 0.1–0.2% of the total land area (Weragodatenna & Gunaratne 2015). Mangrove vegetation can be found in the island along the coastal belt, covering 14 (out of 25) administrative districts; Jaffna, Kilinochchi, Mullaitivu, Trincomalee, Batticaloa, Ampara, Hambantota, Matara, Galle, Kalutara, Colombo, Gampaha, Puttalam and Mannar (Fig. 2) (Kaleel & Nijamir 2017). Mangroves are associated with many of lagoons and estuaries in the island, and hence show patchy distribution (Karunathilake 2003).



Figure 2. Distribution of mangroves in Sri Lanka and its coverage, respect with coastal districts. [Source: Ranawana 2017]

Extensive mangrove patches can be found in the northwestern and northeastern coastlines. The largest patch is associated with Puttalam-Kalpitiya lagoon and the second-largest is located in Jaffna peninsula. Mangrove

forests in Trincomalee and Batticaloa are holding third place in this list (Karunathilake 2003). Less populations in eastern and the northwest part of Sri Lanka could be one of the reasons to have a higher amount of mangroves (Mathanraj & Kaleel 2015). According to Jayatissa (2012) Sri Lanka is enriched with 21 true mangrove species (Table 1) and 24 mangroves associates.

Table 1. Sri Lankan list of true mangrove species

Family	Species
Avicenniaceae	<i>Avicennia marina</i> (Forsk.) Vierh., <i>Avicennia officinalis</i> L.
Combretaceae	<i>Lumnitzera littorea</i> (Jack) Voigt, <i>Lumnitzera racemosa</i> Willd.
Euphorbiaceae	<i>Excoecaria agallocha</i> L., <i>Shirakiopsis indica</i> (Willd.) Esser
Lythraceae	<i>Pemphis acidula</i> J.R. & G. Forst.
Meliaceae	<i>Xylocarpus granatum</i> Koenig
Myrsinaceae	<i>Aegiceras corniculatum</i> (L.) Blanco
Palmae	<i>Nypa fruticans</i> Wurm.
Rhizophoraceae	<i>Bruguiera cylindrica</i> (L.) Blume, <i>Bruguiera gymnorhiza</i> (L.) Lamk., <i>Bruguiera sexangula</i> (Lour.) Poir., <i>Ceriops decandra</i> (Griff.) Ding Hou, <i>Ceriops tagal</i> (Perr.) C.B. Rob., <i>Rhizophora apiculata</i> Bl., <i>Rhizophora mucronata</i> Poir.
Rubiaceae	<i>Scyphiphora hydrophyllacea</i> Gaertn.f.
Sonneratiaceae	<i>Sonneratia alba</i> J. Smith, <i>Sonneratia caseolaris</i> (L.) Engler
Sterculaceae	<i>Heritiera littoralis</i> Dryand.

Source: Jayatissa (2012).

Among the true mangrove species, three are categorized as endangered species, viz., *Ceriops decandra* (Griff.) W.Theob., *Lumnitzera littorea* (Jack) Voigt and *Sonneratia apetala* Buch.-Ham. (Jayatissa 2012, Sarathchandra *et al.* 2018). Most common true mangrove species include; *Rhizophora mucronata* Lam., *Avicennia marina* (Forsk.) Vierh., *Excoecaria agallocha* L., *Lumnitzera racemosa* Willd., *Sonneratia caseolaris* (L.) Engler, *Bruguiera gymnorhiza* (L.) Lamk. and *Aegiceras corniculatum* (L.) Blanco. In addition to the three endangered species indicated above, *Scyphiphora hydrophyllacea* Gaertn.f. and *Cynometra iripa* Kostel. are considered as rare species (Gunawardena *et al.* 2016). Among the mangrove associates, *Acanthus ilicifolius* L., *Hibiscus tiliaceus* L., *Premna integrifolia* L., *Thespesia populnea* (L.) Solander ex Correa, *Acrostichum aureum* L., *Clerodendrum inerme* (L.) Gaertn. (Fig. 3) are the most common species (Jayatissa 2012, Kaleel & Nijamir 2017). Also, in Sri Lanka, endemic species are not found among either true mangrove species or mangrove associates (Jayatissa 2012).

Five types of mangrove vegetation (riverine, fringing, scrub, over-wash and basin) based on the topography, flooding characteristics and floristic composition can be found in the island (Bambaradeniya *et al.* 2002). However, among them riverine and fringing mangroves are the most common types in the island (Jayatissa 2012). For example, *Nypa fruticans* Wurm., *Sonneratia caseolaris*, *Rhizophora apiculata* Bl. and *Bruguiera sexangula* (Lour.) Poir. have been reported from riverine mangroves, while *Rhizophora mucronata*, *Ceriops tagal* (Perr.) C.B. Robinson, *Sonneratia alba* J. Smith and *Avicennia marina* are dominating as fringing mangroves (Gunatilleke *et al.* 2008). Species distribution in the island shows considerable differences, even though they are in the same climatic region or the geographic. This may be due to the hydrology, soil salinity variations and other edaphic factors such as soil nutrition, texture and bulk density in the area (Prasanna *et al.* 2019). As an example, *Avicennia marina* is dominant in the island along with high salinity areas such as southern and western parts of the island (Rajkumar *et al.* 2019). In Sri Lanka mangroves are mainly occur in five provinces; Western, North Western, Northern, Eastern and Southern (Table 2).

Mangroves in Western and North Western Provinces

A study conducted by Prakash and co-workers. (2017) identified that 16 mangrove species, belonging to 9 families are associated with Muthurajawela and Negombo Lagoons, west coast of Sri Lanka (Table 3). However, while moving to north-western coast, Kala oya estuary supports the largest and least disturbed mangrove forest in the island, with an area coverage of over 18.37 km², which belongs to 65% of the mangroves in Dutch bay. In addition to Kala oya, undisturbed mangrove patches can also be found in Kuringipitti, Pubudugama, Gangewadiya, Thirikkapallama, Ettalai and in most of islands such as Ippantivu, Sinnaarichchalai, Periyaarichchalai and Irirmathivu (IUCN, 2012). Kala oya estuary is also enriched with 8 true mangrove species [*Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera cylindrica* (L.) Blume, *Bruguiera gymnorhiza* (L.) Lam., *Ceriops tagal* (Perr.) C.B. Rob., *Excoecaria agallocha*, *Lumnitzera racemosa* Willd. and *Rhizophora mucronata*], while *Rhizophora mucronata* is the most abundant species followed by *Excoecaria agallocha* and *Lumnitzera racemosa*, while *Aegiceras corniculatum* shows the least abundancy (Perera *et al.* 2013).

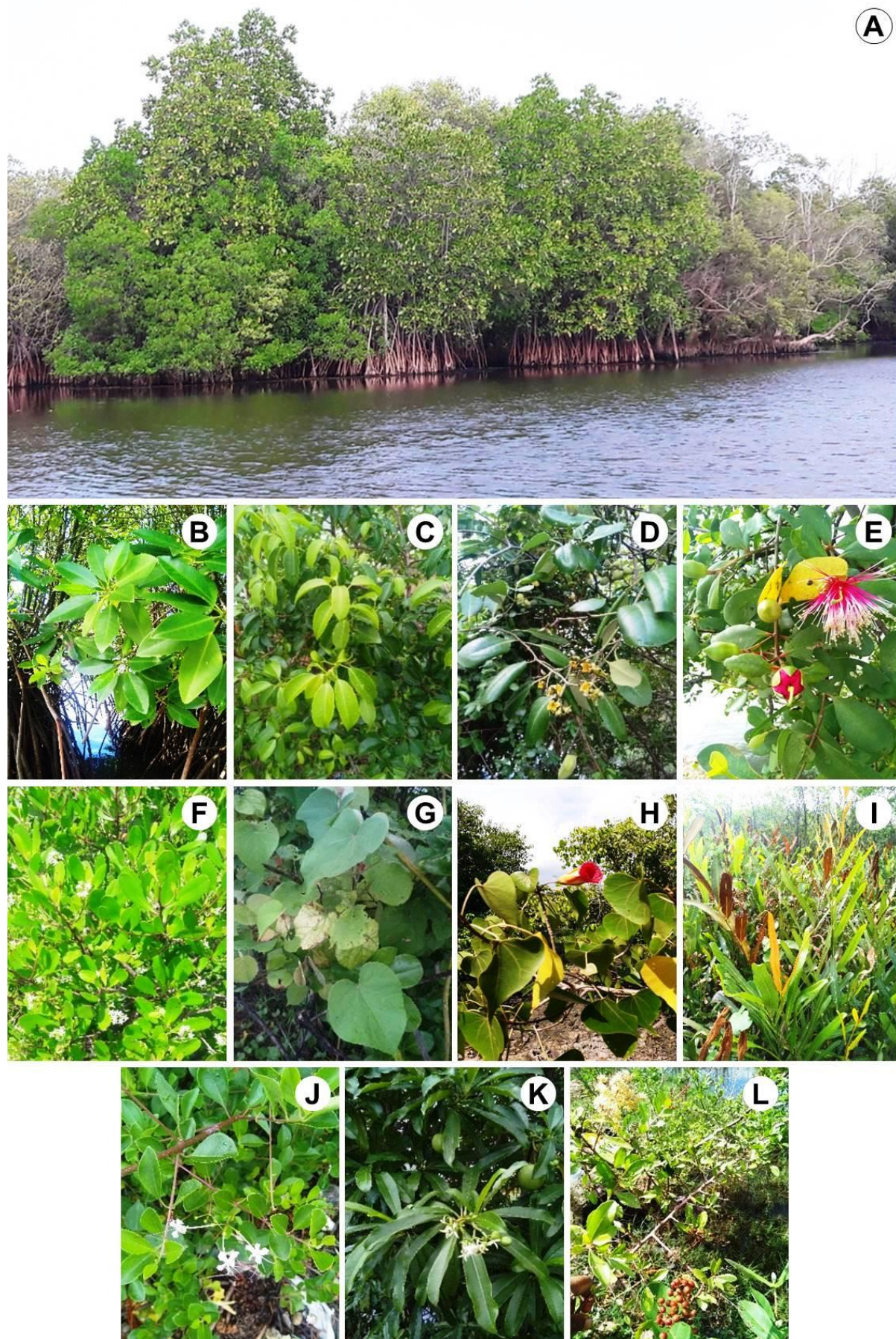


Figure 3. A, Wealthy mangrove forest and some of mangrove species of Sri Lanka; B, *Rhizophora mucronata* Lam.; C, *Excoecaria agallocha* L.; D, *Avicennia officinalis* L.; E, *Sonneratia caseolaris* (L.) Engler; F, *Lumnitzera racemosa* Willd.; G, *Hibiscus tiliaceus* L.; H, *Thespesia populnea* (L.) Solander ex Correa; I, *Acrostichum aureum* L.; J, *Clerodendrum inerme* (L.) Gaertn.; K, *Cerbera manghas* L.; L, *Premna integrifolia* L.

Table 2. List of true mangrove species distribution in Sri Lanka.

Mangrove species	Distribution					References
	WP	NWP	NP	EP	SP	
<i>Aegiceras corniculatum</i> (L.) Blanco	√	√	√	√	√	1,2,4,8,11,13
<i>Avicennia marina</i> (Forsk.) Vierh.	√	√	√	√	√	1,2,4,6,8,9,10,11,12
<i>Avicennia officinalis</i> L.	√	√	√	√	√	1,2,8,11,13
<i>Bruguiera cylindrica</i> (L.) Blume	√	√	√	√	x	1,3,4,7,8
<i>Bruguiera gymnorhiza</i> (L.) Lamk.	√	√	√	√	√	1,2,4,8
<i>Bruguiera sexangula</i> (Lour.) Poir.	√	√	x	√	√	8,13,2
<i>Ceriops decandra</i> (Griff.) Ding Hou	√	√	x	√	x	1
<i>Ceriops tagal</i> (Perr.) C.B. Rob.	√	√	x	x	√	2,4,8
<i>Excoecaria agallocha</i> L.	√	√	√	√	√	1,2,4,5,6,8,10,11,12,13
<i>Shirakiopsis indica</i> (Willd.) Esser	x	√	x	x	√	2
<i>Heritiera littoralis</i> Dryand.	√	√	√	√	√	1,2,6, 8,11
<i>Lumnitzera littorea</i> (Jack) Voigt	√	x	x	x	√	2
<i>Lumnitzera racemosa</i> Willd.	√	√	√	√	√	1,2,4,6,8,10,11,12,13
<i>Nypa fruticans</i> Wurmb.	√	√	x	x	√	2,8
<i>Pemphis acidula</i> J.R. & G. Forst.	√	√	x	√	√	2,13
<i>Rhizophora apiculata</i> Bl.	√	√	x	√	√	1,2,5,6,8,9
<i>Rhizophora mucronata</i> Lam.	√	√	√	√	√	1,2,4,5,8,9,11,14
<i>Scyphiphora hydrophyllacea</i> Gaertn.f.	x	√	√	x	x	1,2
<i>Sonneratia alba</i> J. Smith	√	√	x	x	x	2,8,9
<i>Sonneratia caseolaris</i> (L.) Engler	√	√	√	√	√	1,2,8
<i>Xylocarpus granatum</i> Koenig	√	√	x	x	√	2, 8
Total number of Species	19	21	10	14	17	

Note: √- Presence of the species, x- Absence (or not recorded) of the species; WP- Western Province, NWP- North Western Province, NP- Northern Province, EP- Eastern Province, SP- Southern Province.

Sources: 1. De Silva & De Silva (1998); 2. Jayatissa *et al.* (2002); 3. IUCN (2012); 4. Perera *et al.* (2013); 5. Perera & Amarasinghe (2014); 6. Krishnanantham *et al.* (2015); 7. Packiyannathan & Wijesundara (2016); 8. Prakash *et al.* (2017); 9. Gunathilaka & Chandrasekara (2017); 10. Alawathugoda *et al.* (2018); 11. Ellepola *et al.* (2018); 12. Priyashantha (2018); 13. Prasanna *et al.* (2019); 14. Rajkumar *et al.* (2019).

Table 3. Distribution of different mangrove species in the west coast of Sri Lanka.

Mangrove species	Negambo	Dandugan	Hamilton	Dutch	Ja-ela
	Lagoon	Oya	Canal	Canal	Canal
<i>Aegiceras corniculatum</i> (L.) Blanco	√	x	x	x	x
<i>Avicennia marina</i> (Forsk.) Vierh.	√	x	x	x	x
<i>Avicennia officinalis</i> L.	√	x	x	x	x
<i>Bruguiera cylindrica</i> (L.) Blume	√	x	x	x	x
<i>Bruguiera gymnorhiza</i> (L.) Lamk.	√	√	√	√	√
<i>Bruguiera sexangula</i> (Lour.) Poir.	√	√	√	√	√
<i>Ceriops tagal</i> (Perr.) C.B. Rob.	√	x	x	x	x
<i>Rhizophora apiculata</i> Bl.	√	√	x	x	x
<i>Rhizophora mucronata</i> Lam.	√	x	x	x	x
<i>Excoecaria agallocha</i> L.	√	√	√	√	√
<i>Heritiera littoralis</i> Dryand.	√	√	x	x	x
<i>Lumnitzera racemosa</i> Willd.	√	x	x	x	x
<i>Nypa fruticans</i> Wurmb.	X	√	√	√	√
<i>Sonneratia alba</i> J. Smith	√	x	x	x	x
<i>Sonneratia caseolaris</i> (L.) Engler	√	√	√	√	√
<i>Xylocarpus granatum</i> Koenig	√	x	x	x	x
Total number of Species	15	7	5	5	5

Note: √- Presence of the species, x- Absence (or not recorded) of the species. [Source: Prakash *et al.* (2017)]

About 12 km² of mangrove area was covered around the Puttalam lagoon early and 39% of this mangrove forest has disappeared by 1994 due to the anthropogenic activities and the destruction is still to be stopped (Amarasinghe 1997). In a study by Gunathilaka & Chandrasekara. (2017), 15 total mangrove species (8 True mangrove species and 7 mangrove associates) belonging to 13 genera and 9 families were associated with Puttalam lagoon.

Rhizophora mucronata and *Avicennia marina* were the major constituent mangrove species of Puttalam lagoon area and also in the Dutch bay. *Avicennia marina* can be identified as mono-specific and stands in many places associated with the lagoon. While *Rhizophora mucronata* is distributed widely in water-front areas of

Kala Oya and Mi Oya, rare species *Scyphiphora hydrophyllacea* also can found in associated with Puttalam lagoon in a few locations. *Xylocarpus rumphii* (Kostel.) Mabb. was also restricted to a few small islands in the Puttalam lagoon area (as well as in Wilpattu National Park and Unawatuna Beach) (IUCN 2012). Restricted distribution of *Bruguiera cylindrica* can was also found along the lagoon areas of Chilaw and small islands of Kalpitiya area (IUCN 2012).

Mangroves in Northern Province

Jaffna peninsula bears some large extents of undisturbed mangrove forests (Packiyathan & Wijesundara 2016). *Excoecaria agallocha*, *Lumnitzera racemosa* and *Avicennia marina* are the most frequently found species in Northern Province, including Jaffna, Mullaithivu, Kilinochchi and Mannar districts (Alawathugoda *et al.* 2018). While, *Rhizophora mucronata* is also one of the most common species in the Jaffna district (Rajkumar *et al.* 2019). Also, *Bruguiera cylindrica* shows a much restricted distribution (Packiyathan & Wijesundara 2016), while *Avicennia marina* shows dominant distribution especially in southern and western coastal line of Jaffna (Rajkumar *et al.* 2019).

Ellepola and co-workers (2018) had reported that seven true mangrove species viz., *Avicennia marina*, *Excoecaria agallocha*, *Lumnitzera racemosa*, *Rhizophora mucronata*, *Aegiceras corniculatum*, *Avicennia officinalis* L. and *Heritiera littoralis* Dryand. are associated with Nayar lagoon, Mullaithivu. Furthermore, they found that *Avicennia marina* (relative density 60.6%) as the most dominant species and *Aegiceras corniculatum*, *Avicennia officinalis* and *Heritiera littoralis* as the least abundant species. In addition, *Cynometra iripa* Kostel. found as a rare mangrove associate.

Mangroves in Eastern Province

Most of the mangroves in the Batticaloa district are also distributed as patches and extent of each mangrove patch is less than 0.05 km². Large patches (>1 km²) of mangroves can be found in Trincomalee. Also, over the past decade, about 16% (3.01 km²) of mangrove areas have disappeared (Jayasingam 2008). Shrimp aquaculture, utilization for firewood and security purposes are some of the reasons for destruction of these mangrove forests in the eastern coasts (Jayasingam 2008, Priyashantha 2018).

According to Jayasingam (2008), eastern part of the island possesses about 28–40% mangroves in the country, which includes about 20–25 true mangrove species and a similar number of mangrove associates, though the composition of mangrove vegetation was not included. A study conducted by Krishnanantham *et al.* (2015) found that five true mangrove species (*Avicennia marina*, *Excoecaria agallocha*, *Heritiera littoralis*, *Lumnitzera racemosa* and *Rhizophora apiculata*) were associated with the Irakkandy lagoon. Krishnanantham *et al.* (2015) further indicated that *Avicennia marina* dominated in the area and *Heritiera littoralis* found to be very rare. In addition, restricted growth of *Bruguiera cylindrica* can be found associated with the Trincomalee lagoon (IUCN 2012).

Krishnanantham & co-workers (2015) found that 9 mangrove associates viz., *Caesalpinia bonduc* (L.) Roxb., *Cissus quadrangularis* L., *Clerodendrum inerme*, *Mimusops elengi* L., *Pandanus tectorius* Parkinson ex Du Roi, *Phoenix pusilla* Gaertn., *Premna integrifolia*, *Salvadora persica* L. and *Thespesia populnea*. Being a part of the eastern province, coastline of Batticaloa possesses several common mangrove species including, *Rhizophora*, *Bruguiera*, *Lumnitzera*, *Avicennia*, *Sonneratia* and *Excoecaria*, along with mangrove ferns *Achrosticum* and *Acanthus illicifolius* L., while *Cerbera manghas* L. can be found in association and *Dolichandrone* sp. can be found in Mattakkali, Batticaloa. Nevertheless, species like *Xylocarpus* sp. is rarely found and not properly documented in the recent past (Jayasingam 2008).

In another study, Priyashantha (2018) had reported of less disturbed mangrove forests in association with Panichchankeni lagoon, while *Avicennia marina* as the most frequently and densely distributed vegetation, followed by *Excoecaria agallocha* and *Lumnitzera racemosa* and *Hibiscus tiliaceus* had been the most common mangrove associate. As evidenced by Perera & Amarasinghe (2014), *Rhizophora mucronata* is the other major species in Panichchankeni lagoon, while *Rhizophora apiculata* and *Excoecaria agallocha* were the dominant species associated with Batticaloa lagoon (Perera & Amarasinghe 2014).

While moving to the Ampara district, Prasanna *et al.* (2019) found eleven true mangrove species and among them, *Lumnitzera racemosa* and *Excoecaria agallocha* were recorded as the commonly distributed species. However, according to Prasanna *et al.* (2019), *Aegiceras corniculatum*, *Avicennia officinalis*, *Bruguiera sexangula* and *Pemphis acidula* J.R. & G. Forst. showed restricted distribution in the Ampara district. They further found that 9 and 6 species were associated with the Panama and Pottuvil lagoons respectively and rather less number of mangrove species were associated with creeks and the estuary in the district (Table 4).

Table 4. Distribution of Mangroves in Ampara district, Sri Lanka.

Mangrove Species	Panama Lagoon	Pottuvil Lagoon	Ragamwela Creek	Okanda Creek	Heda oya Estuary
<i>Aegiceras corniculatum</i> (L.) Blanco	x	√	x	x	x
<i>Avicennia marina</i> (Forsk.) Vierh.	√	x	√	√	x
<i>Avicennia officinalis</i> L.	√	x	x	x	x
<i>Bruguiera gymnorhiza</i> (L.) Lam.	√	√	x	√	√
<i>Bruguiera sexangula</i> (Lour.) Poir.	√	x	x	x	x
<i>Rhizophora apiculata</i> Bl.	√	x	x	x	√
<i>Rhizophora mucronata</i> Lam.	√	√	x	√	x
<i>Heritiera littoralis</i> Dryand.	x	√	x	x	√
<i>Lumnitzera racemosa</i> Willd.	√	√	√	√	√
<i>Pemphis acidula</i> J.R. & G. Forst.	√	x	x	x	x
<i>Excoecaria agallocha</i> L.	√	√	√	√	√
Total number of Species	9	6	3	5	5

Note: √ - Presence of the species, x- Absence (or not recorded) of the species. [Source: Prasanna *et al.* (2019)]

Mangroves in the Southern Province

Southern part of Sri Lanka also has a healthy mangrove ecosystem, especially associated with Rekawa Lagoon (Hambantota District), which is surrounded by mangrove and scrub forests (about 2 km²) (Lowry *et al.* 1999). Jayatissa *et al.* (2002) identified 20 true mangroves and about 18 mangrove associates along the south-western coast. Rakawa Lagoon is responsible to have the highest true mangrove diversity in southern Sri Lanka (Jayatissa *et al.* 2006). Mangrove forest also well enriched with 17 mangrove species including all the Sri Lankan common mangroves (Gunawardena & Rowan 2005, Jayatissa *et al.* 2006). In addition, Madu Gaga estuary, which belongs to Galle District is also enriched with mangrove diversity, including a small population of *Lumnitzera littorea*, the species that is very rare and threatened in the island (Bambaradeniya *et al.* 2002). In a study, Bambaradeniya and co-workers. (2002) had recorded a total of 14 species of true mangroves and mangrove associates. *Rhizophora apiculata* found to be the most abundant, while *Lumnitzera littorea* had been the least found species.

Fauna associated with mangroves

Unique features of mangrove ecosystem, support to establish a diverse group of fauna (Miththapala 2008, Sandilyan & Kathiresan 2012) and in Sri Lanka, it has been reported that 66 species of resident birds, 15 species of migratory birds, 37 species of lagoon fish, 9 species of mangrove crustaceans, 6 species of mammals, and 6 species of reptiles were associated with the mangrove ecosystem in the Rekawa lagoon system (Gunawardena & Rowan 2005). In Sri Lanka, more than 100 bird species can be observed associated with mangrove forests. However, all of them are not confined to mangroves and a higher abundance of bird species could be seen associated with dry zone mangrove forests rather than the wet zone forests. Big mammals like *Elephas maximus maximus* and carnivore species like *Panthera pardus kotiya* are also regularly visit mangrove forests (Karunathilake 2003). Table 5 indicates some of the fauna associated with mangroves in the island.

Table 5. Fauna associated with mangrove swamps in Sri Lanka.

Category	Reported species
Birds	<i>Anastomus oscitans</i> , <i>Ardeola grayii</i> , <i>Phalacrocorax</i> spp., <i>Egretta</i> spp., <i>Halcyon pileata</i> , <i>Mycteria leucocephala</i> , <i>Streptopelia chinensis</i> , <i>Vanellus indicus</i> , Owl, Plover, etc.
Fish	<i>Arius maculatus</i> , <i>Caranx sexfasciatus</i> , <i>Chanos chanos</i> , <i>Cyprinus carpio</i> , <i>Epinephelus malabaricus</i> , <i>Eetroplus maculatus</i> , <i>Eetroplus suratensis</i> , <i>Lates calcarifer</i> , <i>Lethrinus</i> sp., <i>Mugil cephalus</i> , <i>Oreochromis mossambicus</i> , <i>Siganus</i> sp., etc.
Crustacean	<i>Metapenaeus dobsoni</i> , <i>Metapenaeus monoceros</i> , <i>Metopograpsus messor</i> , <i>Metopograpsus thukuhar</i> , <i>Penaeus indicus</i> , <i>Penaeus monodon</i> , <i>Penaeus semisulcatus</i> , <i>Perisesarma bidens</i> , <i>Portunus pelagicus</i> , <i>Portunus sanguinolentus</i> , <i>Scylla serrata</i> , <i>Thalassina anomala</i> , <i>Uca annulipes</i> , etc.
Mollusca	<i>Cerithidea cingulate</i> , <i>Nerita polita</i> , <i>Telescopium Telescopium</i> , <i>Terebralia palustris</i> , etc.
Amphibians	<i>Bufo melanostictus</i> , <i>Limnonectes limnocharis</i> , etc.
Mammals	Rabbits, Monkeys.
Reptiles	<i>Crocodylus palustris</i> , <i>Crocodylus porosus</i> , <i>Geochelone elegans</i> , <i>Varanus salvator</i> , Python, Cobra, etc.

Sources: Karunathilake (2003); Jayasingam (2008); Prakash *et al.* (2017); Jonsson (2017); Priyashantha (2018).

Utilization of mangroves and its products

Mangroves utilization in the island may be a traditional practice of the nation and poverty of the local people may be a reason for them to use the mangroves (Dayalatha & Ali 2018). Locals mainly utilized the mangrove areas to capture fish, crabs, shrimps and bivalves, and selling those for small markets and as well for household consumption (Satyanarayana *et al.* 2013).

Rather than that mangroves are directly utilized by the locals in many different ways (Fig. 4). Leaves of *Avicennia* spp. are used by the locals as agricultural manure, while stem is used as firewood and wood is used for home construction (Ranawana 2017). Branches of *Avicennia* spp. are used for Brush pile traditional fisheries. Prop roots from mangrove species like *Rhizophora apiculata* are used as fuelwood (Satyanarayana *et al.* 2013). Some mangrove species are cut down by the locals to obtain sticks for brooms and sweepers, making fish traps, fishing rods, stilt making, poles for fences and posts (Kaleel & Nijamir 2017, Dayalatha & Ali 2018).

Several mangrove species (especially *Lumnitzera* and *Rhizophora* spp.) are used for brush pile fisheries (Ranawana 2017). Tender leaves of *Avicennia marina* are used as a vegetable (Katupotha 2016). Because of its very less weight, wood of *Cerbera manghas* is used by Sri Lankans to carve masks and puppets (Miththapala 2008). *Clerodendrum inerme*, *Dolichandrone spathacea* (L.f.) K. Schum. and *Morinda citrifolia* L. are specially used as firewood, while, *Ceriops tagal* also is used as firewood. In addition, bark of the stem is utilized in several ways such as to prepare tannin, bark decoction is used to stop hemorrhage, as an adhesive, for fishing net protection, batik and mat making. Rather than *Ceriops tagal*, barks of *Xylocarpus* spp. (*X. granatum* Koenig and *X. molluccensis* (Lam.) M.Roem.) and *Bruguiera* spp. (*B. gymnorhiza* and *B. sexangula*) are used to extract tannin, which is important to dye cotton fish nets and sails of boats and ships (Katupotha 2016, Ranawana 2017). Seeds of *Cynometra iripa* are traditionally used instead of areca nuts, while *Sonneratia alba*, *Thespesia populnea* and other *Sonneratia* spp. are used to feed domesticated animals like goats and cattle (IUCN 2012, Katupotha 2016). Moreover, *Nypa fruticans* is used to make alcohol, sugar and vinegar though in Sri Lanka it is minimally practiced at present (Ranawana 2017). Tender leaves of *Sonneratia caseolaris* are traditionally used as a curry and water from the boiled leaves are used as an anti-poison (Bandaranayake 1999). In addition, fruits of *Sonneratia caseolaris* are used to prepare a soft drink (Ranawana 2017). Rather than *Sonneratia caseolaris*, leaves of *Acrostichum aureum* and *Suaeda maritima* (L.) Dumort. are also used as vegetables (IUCN 2012). Pneumatophores of *Sonneratia* spp. are porous, and used as bottle stoppers and fishing floats (Katupotha 2016).

Threats on Sri Lankan mangroves

In Sri Lanka, mangroves are probably the most misused resource in coastal ecosystems (Ranawana 2017). Use of mangrove areas for garbage disposal indicates how poorly island people look into this valuable ecosystem (Dayalatha & Ali 2018). During the last few decades, mangrove forests have been cleared in Sri Lanka in a rapid rate. This has led to a decline of the overall composition of mangrove forests along with a threat to disappearing some of rare species (Jayatissa *et al.* 2002). Estimation shows that 76% of mangrove forests in the island disappeared over the past century (Prakash *et al.* 2017).

Overexploitation of mangroves for traditional uses and growing population in the coastal region and hence land clearance for human settlements are some of the major and common problems for the mangrove destruction in the island. In addition, degradations of mangrove forests also have happened due to industrial activities (*e.g.*, disposal of industrial wastes), tourism, coastal aquaculture and agriculture (*e.g.*, vegetable fields, coastal paddy cultivation), as well due to land reclamation (Katupotha 2001, Bambaradeniya *et al.* 2002, Dayalatha & Ali 2018). A study by Kaleel & Nijamir (2017) showed that construction of tourist hotels and beach resorts in Puttalam, has led to clearance of mangroves in coastal areas of Puttalam, mainly associated with Puttalam lagoon.

Dayalatha & Ali (2018) identified that small scale mangrove cutting for fuelwood and timber as the most common threat to the Sri Lankan mangroves and they had revealed that coastal communities who are living in the Southern coast of Sri Lanka utilize the mangroves extensively as a fuel-wood. They also had stated that mangrove species such as *Excoecaria agallocha*, *Bruguiera sexangula*, *Sonneratia caseolaris*, *Cerbera odollam* Gaertn., *Dolichandrone spathacea*, *Thespesia populnea* are utilized by the communities. Dayalatha & Ali (2018) further states that low income, quick accessibility, less usage of gas for cooking, employment status (*e.g.*, fishing), less education and rural living are the main socio-economic factors to utilize mangroves extensively. IUCN (2012) states that *Cynometra iripa* and *Scyphiphora hydrophyllacea* have been threatened due to the extensive use of these as fuel-wood by local communities in Puttalam Lagoon. In another study, Kaleel & Nijamir (2017) reported that clearance of mangrove forests for the expansion of large playground areas, especially in Puttalam, Kurinchipitti, Thillaiyadi and Wattala. In addition, mangroves are also subject to

significant grazing by cattle and goats, particularly during the dry season (IUCN 2012).

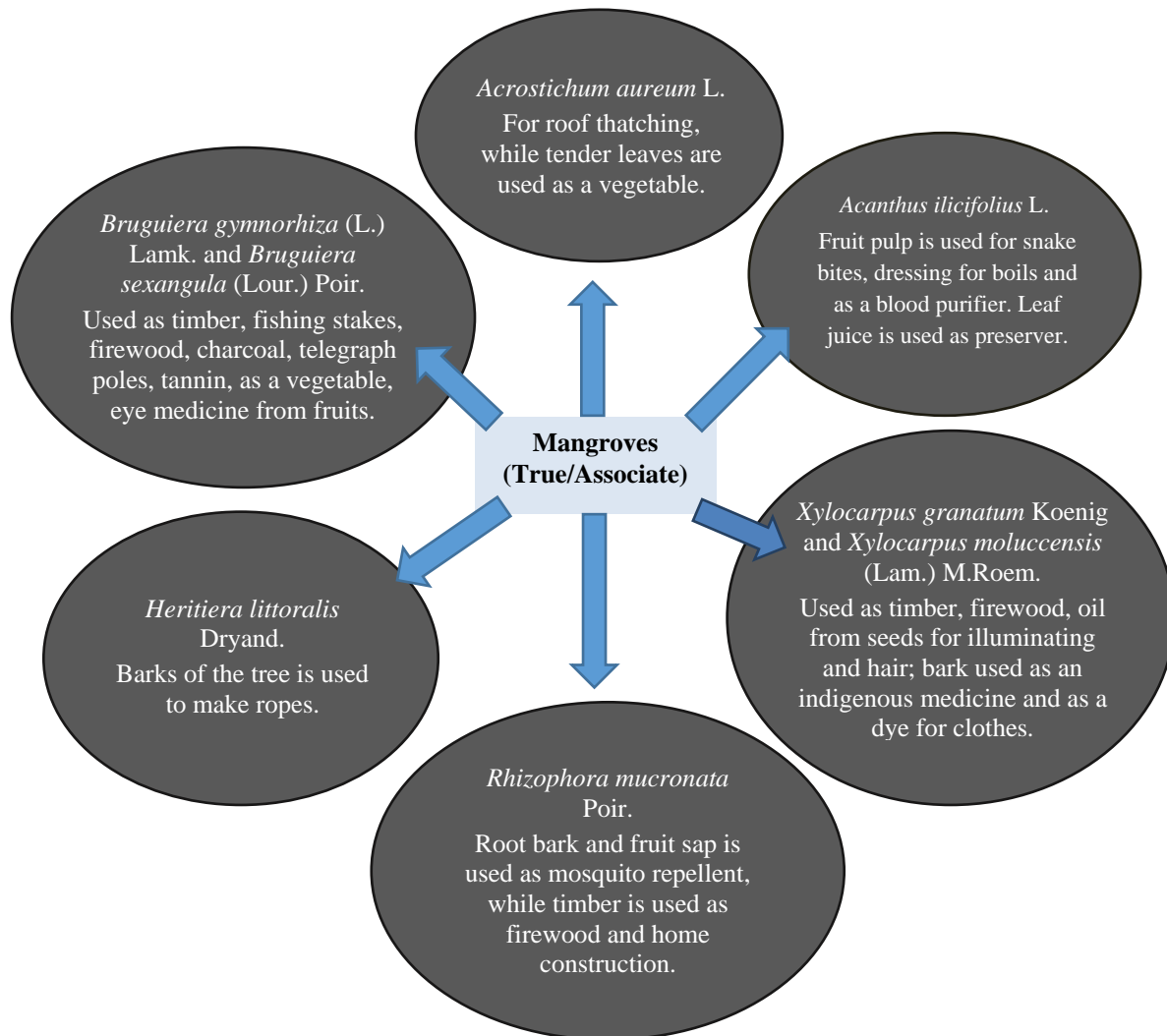


Figure 4. Some uses of Mangroves in Sri Lanka. [Source: Katupotha 2016]

Further establishment of mangrove saplings in eroded areas are also prevented due to the operation of boats at regular intervals due to its constant turbulence (Bambaradeniya *et al.* 2002). Mangrove patches in the island are highly vulnerable for destruction due to shrimp farming, salt manufacturing and other development projects such as road constructions (Alawathugoda *et al.* 2018). Shrimp farming industry caused severe damage to the mangrove ecosystem in the Puttalam district. Illegal destruction of mangrove habitat has caused number of environmental and socioeconomic effects (Munasinghe *et al.* 2010). Worst effect to the mangrove ecosystem in the Puttalam district had taken place during the 1992–1998, where more than 50% of mangroves have been cleaned due to shrimp aquaculture (Harkes *et al.* 2015). Within 1998–2000, 13.71 km² of mangrove forests were destroyed due to the construction of shrimp ponds. The rapid expansion of salt industry, during 2000–2015, was also responsible to deforestation of the mangrove forests in the Puttalam and it is predicted that further decline of mangrove forests by 7% in Puttalam in 2020 (Weragodatenna & Gunaratne 2015). However, due to the higher profits and the foreign exchange coming from shrimp aquaculture in Sri Lanka, value of the mangrove forests had been overlooked (Gunawardena & Rowan 2005).

Conservation of mangroves in Sri Lanka

Sri Lankan government has taken many steps in order to protect this valuable ecosystem including implementing the legislations. Sri Lanka claims to be the first nation in the world to protect all its mangroves, making it illegal to cut down them anywhere in the island, and the first to open a mangrove museum (in Pabbala, Chilaw). Sri Lanka has also named as a leader for conservation of mangroves in Commonwealth countries (Mombauer 2019).

Rather than the government, many NGOs (Non-Governmental Organizations), CBOs (Community-based Organizations) and multilateral financial agencies have taken steps to conserve the mangroves in the island. Restoration of tsunami hit mangrove forests, which are located in east, west and south of the country is one of

the leading example of conserving mangrove vegetation (Sri Lanka National Strategy and Action Plan 2009). Nevertheless, about 23 of project sites (with 67 planting efforts) have been delivered to restore the 10–12 km² of mangrove forest areas (Kodikara *et al.* 2017). However, most of the restoration practices have been failed (9 out of 23 project sites and 36 out of 67 planting efforts did not succeed) and about 2.0–2.2 km² mangrove restoration were succeeded. Successful restoration practices are carried out in Kalpitiya, Pambala, and Negombo area (Kodikara *et al.* 2017). Failure of mangrove restorations happened due to several reasons like planting mangrove seedlings at the inappropriate topography and hydrology, disturbance and stress caused by cattle trampling, browsing, algal accumulation and insect attacks *etc.* (Kodikara *et al.* 2017). In addition, unregulated mangrove plantations (*e.g.*, Batticaloa and in Rekawa Lagoon) could lead to conflicts with fishermen due to loss of fishing areas (Sri Lanka National Strategy and Action Plan 2009).

Nevertheless, long-term sustainability of mangrove rehabilitation also was challenged due to lack of continuous benefits to the neighboring communities and lack of awareness (Prof. P. Vinobaba, Personal communication). Conservation of mangrove forests are also threatened by the gaps of rules and regulations. In Sri Lanka, coastal zone is governed by the Coastal Conservation Act, while mangroves are governed by the Forest Ordinance. It can create disputes due to poor enforcement of both laws (Miththapala 2008). However, still, not enough attention has been paid to conserve the very rare and endangered mangrove species and further steps have not been taken even to educate the locals about those species. In addition, any continuous observations or assessments have not been carried out on the conserved mangrove forests (Jayatissa *et al.* 2002).

CONCLUSIONS AND RECOMMENDATIONS

Mangroves in Sri Lanka show very little coverage, which is estimated about 0.24% of the total land. Distribution of mangroves in Sri Lanka can be found associated with all the coastal districts and hence provinces. True mangrove species such as *Aegiceras corniculatum*, *Avicennia marina*, *Avicennia officinalis*, *Bruguiera gymnorhiza*, *Excoecaria agallocha*, *Heritiera littoralis*, *Lumnitzera racemose*, *Rhizophora mucronata* and *Sonneratia caseolaris* are common to all the coastal provinces in the island. However, owing to several factors including hydrodynamics, species composition and community structure are varied. North Western Province bears the highest mangrove diversity followed by Western and Southern Provinces. The largest mangrove coverage is found in Jaffna district (Northern Province), while least in Matara district (Southern Province).

Being a small island nation, it can never underestimate the importance of mangrove vegetation. Since people in the island still have not seemed to properly understand the function and importance of this ecosystem, the destruction of mangroves is at a considerable rate. Multiple threats such as shrimp aquaculture, tourism, overexploitation, human settlements and a variety of other commercial and industrial activities has led to the reduction of the mangrove coverage. To overcome these issues, some measures are needed to be taken by the government. Protection of mangrove forests just by implementing laws, never to be seen as sufficient to save this valuable vegetation. Continuous monitoring of threats towards the mangrove destruction also needs to be carried out. Complete banning the entry into the mangrove forests may not be a better idea to follow.

One of the best ways to protect the mangrove vegetation would be to create coast benefits towards the adjacent locals and motivate them to protect the vegetation. This can be achieved by promoting ecotourism in the island. Other protection measures include enhancement of public awareness and avoid the overexploitation of mangroves, different stakeholder participation to protect the mangroves, continuous assessment about mangrove declining, promote research and studies on mangroves, carried out proper replanting activities by engaging the expertise or scientific communities covering all the coastal districts, continuous monitoring of restored plantation for its long-term conservation, establishment of an adequate number of mangrove nurseries and research centres and assessment about the effective land use planning.

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