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A review of the floral composition and distribution of mangroves in Sri Lanka

L. P. JAYATISSA[1*], F. DAHDOUH-GUEBAS[2] and N. KOEDAM[2]

[1]*Department of Botany, University of Ruhuna, Matara, Sri Lanka*
[2]*Laboratory of General Botany and Nature Management, Mangrove Management Group, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium*

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Recently published reports list numbers and distributions of Sri Lankan mangrove species that outnumber the actual species present in the field. The present study serves to review this literature and highlight the causes of such apparently large species numbers, while providing an objective and realistic review of the mangrove species actually present in Sri Lanka today. This study is based on standardized fieldwork over a 4-year period using well-established diagnostic identification keys. The study indicates that there are at present 20 identified 'mangrove species' (major and minor components) and at least 18 'mangrove associates' along the south-western coast of the island, and addresses the importance of clearly defining these terms. Incorrect identifications in the past have adversely affected interpretation of species composition in the framework of biogeography, remote sensing and biological conservation and management.

ADDITIONAL KEYWORDS: biogeography – conservation – identification errors – mangrove associates – remote sensing – species composition.

INTRODUCTION

Mangrove communities comprise a group of biotic components, including plants, animals and microbial organisms, that are highly adapted to intertidal environmental conditions. However, none of these can be identified as a community in a mangrove ecosystem without the actual mangrove plants (trees and shrubs), implying that the true mangrove vegetation is the major constituent of the ecosystem. Mangrove vegetation defines the landscape and participates directly or indirectly in the ecological processes that take place in this ecosystem (Lugo & Snedaker, 1974; Hamilton & Snedaker, 1984; Tomlinson, 1986). Therefore, knowledge of the exact species plant composition of mangroves in any country is a basic and important prerequisite to understanding all the aspects of structure and function of mangroves, as well as their biogeographical affinities and their conservation and management. The past and present distribution of mangroves has been reviewed by several authors on a global level (e.g. Tomlinson, 1986; Ricklefs & Latham, 1993; Duke, 1995; Duke *et al.*, 1998; Ellison *et al.*, 1999). In this paper, we focus on the distribution of mangroves in south-western Sri Lanka.

The species richness of mangroves in many geographical areas is decreasing with time as a result of the destruction of mangrove forests and exposure to various anthropogenic stresses (Hamilton & Snedaker, 1984). The area and floristic composition of mangrove forests in Sri Lanka has also decreased at a rapid rate during the last few decades (Pernetta, 1993; Corea *et al.*, 1995; Dahdouh-Guebas *et al.*, 2000; De Silva & Balasubramaniam, 1984–85), possibly leading to the local extinction of some rare species. Peculiarly, some recent documents from governmental and national institutes have reported a number of new records of mangrove species for Sri Lanka; these publications (e.g. Liyanage, 1997) have erroneous species identifications and list many more mangrove species

*Corresponding author. E-mail: lpj@bot.ruh.ac.lk

than are present in reality. There is also a general trend amongst researchers when reporting the total number of mangrove species to include mangrove associates or beach vegetation that occur occasionally within the mangrove. The danger of such reports, particularly if of governmental origin (e.g. from a national Forest Department), is that authors seeking data on national mangrove species distribution can be readily misled by them. Unfortunately, the inclusion of fictional and non-mangrove species lessens the value of such species distributional data and may lead to incorrect conclusions being drawn in the framework of, for instance, biogeographical research.

The objectives of this study are to review the existing literature on Sri Lankan mangrove species and to provide an up-to-date list of the floral composition of mangrove ecosystems in Sri Lanka, emphasizing 'mangrove species' and 'mangrove associates' (see below). The possible effects of erroneous mangrove species lists are discussed in the contexts of biogeography, remote sensing and biological conservation.

MATERIAL AND METHODS

Mangrove definitions

Proper definition for mangrove plants is a prerequisite to determining the species richness of mangroves in any geographical area. Up to now, no absolute definition to distinguish clearly between the mangrove and non-mangrove species has been used. This can in part be explained by the merging of mangrove vegetation with salt marsh, seashore, fresh-water marsh or other terrestrial vegetation bordering mangals and the introgression of eurytopic species. Non-mangrove vegetation generally occurs at the landward margins of mangroves or at the freshwater influx side.

To reduce some of the confusion, several authors have recognized two categories of plants in mangrove communities as 'plants which are restricted to mangrove habitats' and 'plants which are not restricted to mangrove habitats'. However, the terminology of these two categories varies according to the author. Lugo & Snedaker (1974) and Arulchelvam (1968), for instance, named the categories as 'true mangroves' and 'mangrove associates' whilst Saenger *et al.* (1983) and Ricklefs & Latham (1993) designated them as 'exclusive mangroves' and 'non-exclusive mangroves'. These two groups have been further subdivided and separated in a more descriptive way by Tomlinson (1986) and named 'major mangrove components = true or strict mangroves', 'minor mangrove components' and 'mangrove associates'. In the present study we follow this division and, like Tomlinson, use the term 'mangrove species' to refer to the first two groups. Duke (1992) prepared the ground for a better definition of what is a mangrove and what is not, and he highlighted that the emphasis of the definition should be on the species which 'normally' grow in the intertidal zone; 'normally' being defined on the basis of wide-ranging field observations. The definition that Duke (1992) adopts for a mangrove is a 'tree, shrub, palm or ground fern, generally exceeding one half meter in height, and which normally grows above mean sea level in the intertidal zone of marine coastal environments, or estuarine margins'. We decided, however, to consider the genus *Acrostichum* as a mangrove associate in this study, unlike Tomlinson (1986) or Duke (1992), for the following three reasons: first, it is by no means restricted to mangrove ecosystems in Sri Lanka (pers. observ.) and it is also known to occur elsewhere away from mangroves (Adams & Tomlinson, 1979; Tomlinson, 1986); second, unlike all the other minor mangrove components, which are woody, it is a ground fern and hence did not allow the same scientific approach as used in the study of the vegetation ecology of woody plants (e.g. it does not allow the measurement of common forestry characteristics in what are often virtually monospecific stands); and third, it is often considered a pest by local mangrove managers and is therefore rigorously removed when rehabilitating sites (J. G. Kairo, pers. comm.).

Fieldwork

Along the coastal belt of Sri Lanka, over a distance of approximately 390 km ranging from Palatupana (6°14′ N, 81°14′ E) to Puttalam (8°07′ N, 81°46′ E), all mangrove communities were visited and the species composition recorded (Fig. 1). At present, due to political unrest, this section is the only safely accessible part of the coastal belt. It represents, however, all the climatic divisions (Mueller-Dombois, 1968) and most of the major soil types (Panabokke, 1967) characteristic of coastal areas of Sri Lanka. For our purposes, we group the climatic divisions of Sri Lanka into 'wet', 'dry' and 'intermediate' zones after Mueller-Dombois (1968) (see Fig. 1). Mangrove populations along the study section of coast, and within each site those parts of the mangrove with different physiognomic aspects, were visited from 1996 to 1999. All vascular plants and ferns were identified in the field using Duke & Bunt (1979), Tomlinson (1986), Duke & Jackes (1987), Banerjee *et al.* (1989), Duke (1991) and the Revised Series of the Flora of Ceylon (Dassanayake & Fosberg, 1980; Dassanayake & Fosberg, 1981a, 1981b; Dassanayake & Fosberg, 1983; Dassanayake & Fosberg, 1985; Dassanayake & Fosberg, 1987; Dassanayake & Fosberg, 1991; Dassanayake *et al.*, 1994, 1995, 1996, 1997, 1998). Herbarium specimens for all the true mangrove species and common mangrove associates were prepared. The fresh or herbarium specimens were checked against the ones present in the National

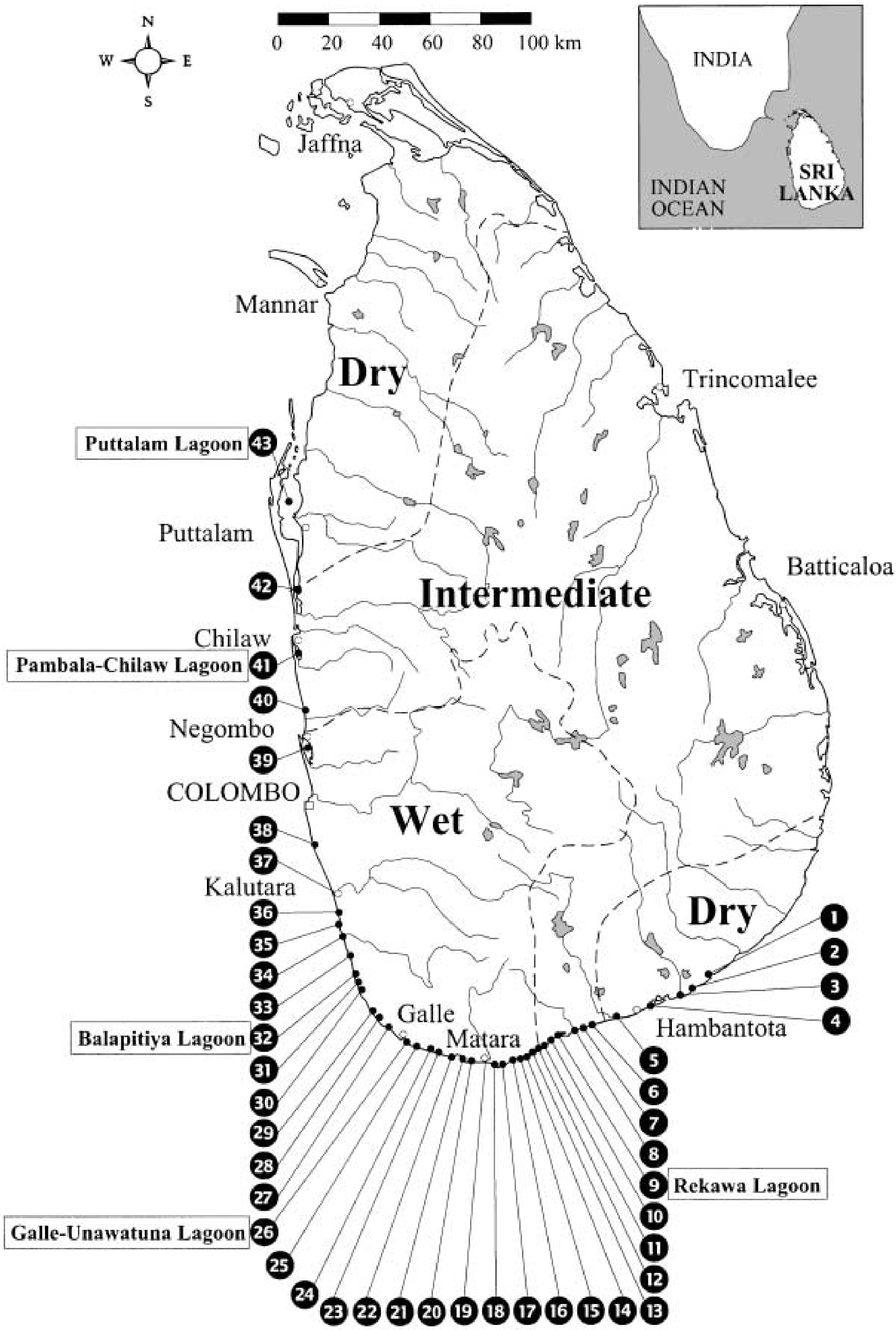

Figure 1. Map of Sri Lanka showing the different climatic zones (Mueller-Dombois, 1968) and some of the major cities along the coast. Dots represent the lagoons investigated (see Appendix 1 for definition of codes). The names of the five representative mangrove lagoons (Table 1) are indicated in boxes.

Herbarium at the Royal Botanical Gardens in Peradeniya (Sri Lanka) and against collections from the Department of Botany at our home university, where they were also kept. All sites have been visited at least once at the time of flowering of the different species to cross-check identification with flower-based diagnostic features. The total abundance of plants was estimated based on the best professional judgement from field visits and field knowledge, and expressed as 'very common', 'common', 'rare' or 'very rare'. Seven mangrove lagoon communities (Lunama, Kalamatiya, Rekawa, Dondra, Unawatuna-Galle, Negombo and Pambala-Chilaw; see Fig. 1) covering a distance of 270 km along the coastal belt were studied in detail in the framework of related studies on mangrove ecology (Jayatissa, 1987; Ladavid 1995; Thomaes, 1996 ; Verheyden, 1997; Zetterström, 1998; Dahdouh-Guebas *et al.*, 2000, in press; Deschuytter, 2000; Dahdouh-Guebas, 2001; Verheyden *et al.* in press).

Altogether, 43 mangrove communities bordering lagoons, estuaries and other coastal water bodies were recorded on the coastal belt from Palatupana to Puttalam (Fig. 1). Of the localities studied, the Puttalam lagoon had the largest area of mangrove and its extent has been estimated to be about 2970 ha (Jayewardene, 1986). Mangrove communities of moderate areal extent fringe the lagoons of Chilaw, Negombo and Rekawa. All the other mangrove communities were less than 100 ha in area. For some mangroves, it is quite difficult to determine their extent because their boundaries are not clear. In particular, some estuarine mangroves in the wet zone extend backwards to cover extensive river flood plains where mangrove associates (e.g. *Annona glabra* L., *Acrostichum aureum* L., *Cerbera manghas* L. and *Dolichandrone spathacea* (L.f) K. Schumann) are dominant and some true mangrove species occur sporadically.

RESULTS & DISCUSSION

The mangrove communities from Palatupana to Puttalam, are probably representative for the mangrove communities in the whole of Sri Lanka because they are located in areas representing all the climatic zones (Mueller-Dombois, 1968) and most of the major soil types (Panabokke, 1967). Climate and soil texture are two of the major factors affecting the composition and distribution of mangrove species. Apart from some major contiguous areas, such as Negombo Lagoon and Puttalam Lagoon, these mangroves constitute fairly small patches, possibly allowing for a great diversity of ecological conditions and management practices. In total, we found 20 mangrove species along the Sri Lankan south-western coast, all of which were included already in the National Herbarium in Peradeniya.

Sri lankan mangrove species observed in this study

The diversity in mangrove species composition can be seen from Appendix 1. Nine mangrove species were previously recorded from Chilaw Lagoon by the Wetland Conservation Project (1994); however, their conclusion that the biological diversity in this lagoon could have been undervalued because of their incomplete species lists is borne out by the present study, which has recorded 16 species. The higher species richness of mangroves in the intermediate climate zone as compared to the dry or wet climate zone (Table 1; Appendix 1) is probably due to the fact that certain environmental factors may not reach extremes in the intermediate zone, and thus these moderate conditions may favour greater species richness. It is also possible that the variety of habitats available to mangroves is higher in intermediate rainfall areas because there is a mixture of wet and dry sites that are not present at the extremes of the precipitation gradient.

In the discussion below we will focus on the globally polyspecific genera to highlight the diagnostic features we used to distinguish between species.

Within the *Avicennia* genus only *Avicennia alba* Blume, *A. marina* (Forsk.) Vierh. (or *A. marina* var. *marina*), *A. officinalis* L and *A. rumphiana* Hallier f. appear in the Indo-Malaysia biogeographical region and only the former three species reach the Indian subcontinent (Duke, 1991; Duke *et al.,* 1998). In Sri Lanka, the key diagnostic feature to distinguish *A. officinalis* from *A. marina* are the rounded leaf tips of the former species. Although we did not observe *A. alba*, we know that this species has propagules that are elongated and have a sharp tip, unique within the genus. Although there is some plasticity in *Bruguiera* (see below), we could easily distinguish between species with the use of flower characteristics (and with knowledge of the global distribution of each species). The three filamentous appendages on the petals, in open flowers as well as in closed immature flowers, were a diagnostic feature used to differentiate between *B. gymnorrhiza* (L) Lamk. and *B. sexangula* (Lour.) Poir. We found the descriptions given in Tomlinson (1986) useful for this purpose. Tomlinson's diagnostic keys were also used to distinguish between the two species of *Ceriops*. Local knowledge may also be very valuable, and noteworthy in this respect is the field knowledge of Daglas Thisera. Mr Thisera, who grew up in the mangrove, was a fisherman for 18 years after dropping out of school, and was then selected as the Coordinator of Mangrove Conservation and Education at the Small Fishers Federation of Lanka (SFFL). His local knowledge allows him to distinguish between species using an integration of characteristics

Table 1. Distribution of mangrove species (according to Tomlinson, 1986; except the genus *Acrostichum*) and mangrove associates in five representative mangrove forests covering all the climatic zones of Sri Lanka, • denotes occurrence. The abundance scale includes all 43 mangrove communities (+ + = very common; + = common; – = rare; – – = very rare)

	Wet zone		Intermediate zone		Dry zone	
Lagoon:	Galle-Unawatuna	Balapitiya	Rekawa	Pambala-Chilaw	Puttalam	Abundance
MANGROVE SPECIES						
Aegiceras corniculatum (L.) Blanco	●		●	●	●	+
Avicennia marina (Forsk.) Vierh.	●		●	●	●	++
Avicennia officinalis L.			●	●		++
Bruguiera cylindrica (L.) Blume				●	●	–
Bruguiera gymnorrhiza (L.) Lamk.	●	●	●	●		+
Bruguiera sexangula (Lour.) Poir.	●	●	●	●		+
Ceriops tagal (Perr.) C.B. Robinson			●	●	●	+
Excoecaria agallocha L.	●	●	●	●	●	++
Excoecaria indica (Willd.) Muell.-Arg./ *Sapium indicum* Willd.				●		–
Heritiera littoralis Dryand.	●	●	●	●	●	+
Lumnitzera littorea (Jack) Voigt		●				––
Lumnitzera racemosa Willd.	●	●	●	●	●	++
Nypa fruticans (Thunb.) Wurmb.		●	●			+
Pemphis acidula Forst.	●				●	––
Rhizophora annamalayana Kathiresan				?		
Rhizophora apiculata BL.	●	●		●		+
Rhizophora mucronata Lamk.			●	●	●	+
Scyphiphora hydrophyllacea Gaertn.f.					●	––
Sonneratia alba J. Smith				●	●	–
Sonneratia caseolaris (L.) Engler	●			●		+
Xylocarpus granatum König				●		+
Total number of mangrove species	10	8	11	16	11	
MANGROVE ASSOCIATES						
Acanthus ilicifolius L.	●	●	●	●	●	++
Acrostichum aureum L.	●	●	●	●	●	++
Annona glabra L.	●	●		●		+
Barringtonia asiatica (L.) Kurz.	●					+
Barringtonia racemosa (L.) Spreng.	●	●	●			+
Callophyllum inophyllum L.	●	●	●	●	●	+
Cerbera manghas L.	●	●	●	●	●	+
Clerodendron inerme (L.) Gaertn.	●	●	●	●	●	++
Cynometra iripa Kostel			●		●	––
Derris spp.	●	●	●	●	●	+
Dolichandrone spathacea (L.f.) K. Schumann	●	●	●	●		+
Hibiscus tiliaceus L.	●	●	●	●	●	++
Phoenix zeylanica Trim.*		●	●	●		+
Premna integrifolia Lam. (= *P. foetida* Reinw.)	●	●	●	●	●	+
Sphaeranthus amaranthoides Burm. F.			●		●	–
Tamarix galica L.				●	●	–
Thespesia populnea (L.) Soland. ex.Corr.	●	●	●	●	●	++
Total number of mangrove associates	14	13	14	13	12	

* Endemic species.
? Occurrence still to be confirmed (see text).

that go beyond that which is currently translated into diagnostic keys. For instance, his knowledge of the density of the branches and leaf rosettes, and the way that they appear physiognomically, allow him to differentiate between *B. gymnorrhiza* and *B. sexangula*. His identifications were consistently correct when cross-checked with diagnostic keys.

Of the small-flowered *Bruguiera* species, only *B. cylindrica* (L) Blume was encountered, which can be distinguished from *B. parviflora* Wight & Arnold ex. Griffith based on calyx and on relative petal proportions, and from *B. hainesii* C.G. Rogers based on these features as well as on petal length.

Arulchelvam (1968) was the first to report that *Xylocarpus moluccensis* (Lamk.) Roem. occurs in Sri Lanka. However, according to the description and drawings given in his paper, it is obvious that *Cynometra iripa* Kostel was misidentified as *Xylocarpus moluccensis*. The same mistake was made by other authors (e.g. Pinto, 1986). Although De Silva & Balasubramaniam (1984–85) included both *X. moluccensis* and *C. iripa* in their list of mangrove species and referred to Arulchelvam's 1968 study without giving further taxonomic descriptions or localities for either species, the original misidentification by Arulchelvam (1968) was not corrected by them. Although Arulchelvam reported that *X. moluccensis* (in reality *C. iripa*) had been recorded only in Batticaloa lagoon (on the east coast of Sri Lanka), this study now shows that, although still a very rare species, a few specimens of *C. iripa* are actually present in the lagoons of Rekawa and Puttalam (Fig. 1).

The presence of *Xylocarpus moluccensis* or *X. mekongensis* Pierre in Sri Lanka remains doubtful. Although these species have been included in the list of mangrove species by several authors (e.g. Amarasinghe, 1996; Liyanage, 1997), no researcher has given a proper taxonomic description and other authors do not report its presence in publications featuring global mangrove distribution (Tomlinson, 1986; Duke, 1992; Spalding *et al.*, 1997; Duke *et al.*, 1998). A few trees of a halophytic, not mangrove, *Xylocarpus* species that inhabits sandy shores (beach vegetation) were recorded from Unawatuna Bay on the south-western coast of Sri Lanka, at a single location. Its characteristics fit well with the short description given by Tomlinson (1986) for *X. moluccensis*, however it has been identified as *X. rumphii* by Mabberley (1995). Amarasinghe (1996) and Liyanage (1997) also followed the same nomenclature, but categorized it as a mangrove species. Unfortunately, taxonomic descriptions of the less common *Xylocarpus* species are deficient because it was not recognized until fairly recently that flowers are unisexual (Tomlinson, 1986). Within the genus, *Xylocarpus granatum* Koenig can easily be distinguished on the basis of its flaking bark and its very large fruits, at least 20 cm in diameter. In Kenya, many *X. granatum* fruits grow larger than this size (pers. obs.).

Although *Heritiera fomes* Buch.-Ham. occurs on the Indian subcontinent, based on our observations of an extended fruit with a single ridge, we found *H. littoralis* Dryand. to be the only representative species of its genus.

Excoecaria indica (Willd.) Muell.-Arg. was found in considerable numbers in the Tillawatawana Lagoon, Bentota Estuary and Gin Oya, and in smaller numbers in Pambala-Chilaw Lagoon. It may be restricted to mangrove area or appear in the back mangrove where it blends with terrestrial vegetation. It is typically distinguished from *Excoecaria agallocha* L. by its green fruit the size of a cherry, and by its thorny trunk. It is, however, claimed that this species might have been recorded previously in Sri Lanka under the synonym *Sapium indicum* Willd., the nomenclature of which was reported by Philcox (1997). It thus remains unclear whether or not this is the first time *E. indica* (*sensu* Tomlinson, 1986) has been reported in Sri Lanka.

Lumnitzera littorea (Jack) Voigt (= *L. coccinea* Wight & Arnold) and *Scyphiphora hydrophyllacea* Gaertn.f. were recorded 40 years ago for the first time by Abeywickrema (1960) and have now become very rare species in Sri Lanka. At present, a few trees of *L. littorea*, with their typical red flowers, can be seen at one locality in one of the small islands in the Balapitiya estuary (Fig. 1), but 40 years ago it was recorded in the Bentota river estuary as well (Abeywickrema, pers. comm.). A few trees of *Scyphiphora hydrophyllacea* are also restricted to one locality on the Kalpitiya Peninsula in Puttalam lagoon (Fig. 1).

Sonneratia alba J. Smith was recorded in this study as a species with a limited distribution in the dry climate zone and it appears to be replaced by *S. caseolaris* (L) Engler in the wet zone. *Sonneratia apetala* Buch.-Ham, which is perhaps the most distinctive species in its genus because of its tiny fruits, was not reported in this study. It was, however, recorded 20 years ago as a very rare species in Sri Lanka with a population of six trees near Muttur in the estuary of Koddiyar river (Macnae & Fosberg, 1981a,b). However, no recent report exists to confirm its continued survival.

In our study, we encountered only two known representatives of *Rhizophora*: *R. apiculata* Blume and *R. mucronata* Lamk.; identification was based on inflorescences and propagules (cf. Duke & Bunt, 1979), and their relative positions with respect to the leaf rosette. We are not, however, familiar with other *Rhizophora* species that are potentially present in Sri Lanka (e.g. *R. stylosa* Griff., which is present in India, and its possible hybrid *R. lamarckii* Montr. formed together with *R. apiculata* as the second putative parent). In addition, Duke *et al.* (1998) state that major systematic problems exist with the *Rhizophora* genus.

The existence of mangrove hybrids must also be highlighted. A *Rhizophora* species that is probably a hybrid between *R. apiculata* and *R. mucronata* was found in the Pambala-Chilaw lagoon complex, one out of the three sites where both species occur together (Appendix 1). This type of hybrid has so far been named twice: *R. lombokensis* Baba & Hayashi 1994 (Baba, 1994) and *R. annamalayana* Kathiresan (Kathiresan, 1995). Both reports aimed to name the apparently new species without providing much detail about the plant itself. The possible hybrid has not been described in systematic contributions to mangrove literature since its initial report, but its existence was briefly highlighted in a study on the molecular phylogeny of mangroves (Parani *et al.*, 1997). The Sri Lankan putative hybrid is currently the subject of in-depth morphological and genetic study, and preliminary results indicate that it shows morphological differences to *R. apiculata*, whereas genetically it is similar (Jayatissa, Abeysinghe, Hettiarachchi, Dahdouh-Guebas, Duke, Triest and Koedam unpubl. results).

Although no other mangrove hybrids were found during the course of this study, it should be pointed out that there are a number of sites where putative parents from existing hybrids occur together. There is, therefore, always the possibility that the respective hybrids will occur. This is the case for *Lumnitzera rosea* (Gaud.) Presl. (hybrid between *L. littorea* and *L. racemosa* Willd.) in Balapitiya, and *Sonneratia gulngai* N.C. Duke (hybrid between *S. alba* and *S. caseolaris*) in Negombo and Pambala-Chilaw Lagoons. As for the possible putative hybrid between *Bruguiera gymnorrhiza* and *B. sexangula* that apparently exists in Sri Lanka, when such individuals originating from *B. gymnorrhiza–B. sexangula* mixed stands are analysed on a genetic level, they all separate well, with no hybrid position between the two taxa (Abeysinghe *et al.*, 1999; Abeysinghe *et al.*, 2000).

Sri lankan mangrove species reported in earlier studies and by the forest department

Table 2 shows the species compositions of true mangroves in Sri Lanka according to different national and international reports, as well as results observed in the present study. Note that the more recent the national report, the more mangrove species that are recorded. Duke (1992) also reported a steady increase in species numbers for Australia, from 19 to 39 over the last 23 years. If all the literature reports on the species composition in Sri Lankan mangroves were both accurate and precise, then the national total would be 38 species (Table 2), which is approximately the number of species found at longitudes known for their high species richness (between 135°E and 150°E; Tomlinson, 1986; Duke, 1992;Elli son *et al.*, 1999). If filtered according to our definition of mangrove species, the total number of species in Sri Lanka would still amount to 29 species. These findings are interesting because these species records are both restricted to a longitudinal range less than 2°30′ wide (compared to the 15° longitudinal range mentioned above) and to a small area of approximately 10 000 ha (Pemadasa, 1997), which in addition is fragmented to a high degree (De Silva & Balasubramaniam, 1984–85). That the literature reports such high species richness for Sri Lanka is indication of the need for a critical review of which species are actually present, what has lead to the exaggeration of reported species richness, and what are the scientific implications of such inflated lists.

As described above, the 20 mangrove species reported in the present study contrast with an additional 9 to 18 species mentioned in earlier reports. The present study was restricted to southern and western coasts of Sri Lanka, mainly because other coastal areas are not accessible due to the security situation that has prevailed since 1983. However, because all the reports that give additional species were published after 1983, it implies that they too were conducted along the same coastal area as studied here. The reliability of some of these studies is therefore doubtful.

Five species of the additional species mentioned above, i.e. *Avicennia alba*, *Bruguiera hainesii*, *Bruguiera parviflora*, *Kandelia candel* (L) Druce and *Phoenix paludosa* Roxb., were included in the list of national mangrove species for the first time by Rao (1987). It is not clear how these species were incorporated into this report, as a survey on mangroves in Sri Lanka was not actually conducted and the sole publication Rao referred to in order to obtain information on Sri Lankan mangroves is a paper by Jayewardene (1986). This publication does not, however, list any of the above five species. One could infer, without justification, that some of these species may have been included because of their presence in the neighbouring country of India, such as *Kandelia candel* in the Ganges Delta.

Amarasinghe (1996) and Liyanage (1997) give almost identical lists of mangroves in Sri Lanka, including a number of species that were not recorded in our study. However, only the species given by Liyanage (1997), a publication by the Forest Department of Sri Lanka, will be taken into consideration here, as the list given by Amarasinghe (1996) was based on information received from the Forest Department and thus is subject to the same criticism.

It is clear that *Acanthus volubilis* Wall. was included in the list of national species by Liyanage

Table 2. Review of the species composition of mangroves as reported by various Sri Lankan authors. ● = reported by other authors or in this study; ○ = recorded but not considered a true mangrove species. The total number of species for the present study has been calculated from true mangrove species only

Plants listed as mangrove species in scientific literature	Abeywickrema 1960	Arulchelvam 1968	De Silva & Balasubramaniam 1984	Nanayakkara 1986	Pinto 1986	Jayewardene 1986	Rao 1987	Amarasinghe 1996	Liyanage 1997	Jayatissa *et al*. (this study)
Acanthus ilicifolius L.	●	●	●	●	●	●	●	●	●	○
Acanthus volubilis Wall.								●	●	
Acrostichum aureum L.								●	●	○
Acrostichum speciosum Willd.								●	●	
Aegiceras corniculatum (L.) Blanco	●	●	●	●	●	●	●	●	●	●
Avicennia alba Blume							●	●	●	
Avicennia marina (Forsk.) Vierh.	●	●	●	●	●	●	●	●	●	●
Avicennia officinalis L.	●	●	●	●	●	●		●	●	●
Bruguiera cylindrica (L.) Blume	●	●	●	●	●	●	●	●	●	●
Bruguiera gymnorrhiza (L.) Lamk.	●	●	●	●	●	●	●	●	●	●
Bruguiera hainesii C.G. Rogers							●			
Bruguiera parviflora Wight & Arnold ex. Griffith							●			
Bruguiera sexangula (Lour.) Poir.	●		●		●	●	●	●	●	●
Ceriops decandra (Griff.) Ding Hou	●		●		●	●	●	●	●	
Ceriops tagal (Perr.) C.B. Robinson	●	●	●	●	●	●	●	●	●	●
Cynometra iripa Kostel			●							○
Dolichandrone spathacea (L.f.) K. Schumann										○
Excoecaria agallocha L.	●	●	●	●	●	●	●	●	●	●
Excoecaria indica (Willd.) Muell.-Arg./ *Sapium indicum* Willd.										●
Heritiera littoralis Dryand.	●	●	●	●	●	●	●	●	●	●
Kandelia candel (L.) Druce							●			
Lumnitzera littorea (Jack) Voigt	●		●				●	●	●	●
Lumnitzera racemosa Willd.	●	●	●	●	●	●		●	●	●
Nypa fruticans (Thunb.) Wurmb.	●	●	●	●	●	●	●	●	●	●
Pemphis acidula Forst.								●		●
Phoenix paludosa Roxb.							●			
Rhizophora annamalayana Kathiresan										?
Rhizophora apiculata BL.	●	●	●	●	●	●	●	●	●	●
Rhizophora mucronata Lamk.	●	●	●	●	●	●	●	●	●	●
Scyphiphora hydrophyllacea Gaertn.f.	●		●			●	●	●	●	●
Sonneratia alba J. Smith			●		●	●	●		●	●
Sonneraria apetala Buch.-Ham			●		●	●		●		
Sonneratia caseolaris (L.) Engler	●	●	●	●	●	●	●	●	●	●
Sonneratia griffithii Kurz								●	●	
Sonneratia ovata Backer								●	●	
Xylocarpus granatum König		●	●	●	●	●	●	●	●	●
Xylocarpus moluccensis (Lamk.) Roem.		●	●	●	●	●	●	●		
Xylocarpus mekongensis Pierre								●	●	
Xylocarpus rumphii								●	●	○
Total number of species	18	16	23	16	20	21	25	29	28	20 (+ 1?)

? Occurrence still to be confirmed

(1997) as a result of obvious misidentification. According to Tomlinson (1986) and Banerjee *et al.* (1989) the diagnostic differences between *Acanthus ilicifolius* L and *A. volubilis* are as follows: the corolla of *A. ilicifolius* is blue or violet, but rarely white, bracteoles are persistent, plants are robust and erect with spiny leaves, but sometimes leaves can be spineless. The corolla of *A. volubilis* on the other hand, is always white, bracteoles are absent, plants are usually unarmed and twining with delicate sprawling stems. The description and photographs given in Liyanage (1997) for *A. volubilis* reveal that the only character of the observed specimen used to identify the species is the white colour of the flowers; however, this can be a feature of *A. ilicifolius* as well (see description; pers. obs.). In the present study, we have inspected herbarium and live specimens located in Pambala-Chilaw lagoon (one of our main mangrove ecosystem research areas) of the plant recorded by Liyanage (1997) to be *A. volubilis*, and confirm that it is a whitish flowered form of *A. ilicifolius*, based on diagnostic characteristics of flowers, fruits and general plant morphology (e.g. the same plant also carries purple flowers, the fruits are large, the plant is always very spiny). In addition, the purple colour of the stem, claimed by Liyanage (1997) to be another characteristic of *A. volubilis*, is not evident from the photographs given and is in our opinion yet another very plastic morphological characteristic. *A. ilicifolius* specimens have been recorded with stems that are green, purple or of colours in between (pers. obs.). Sri Lankan field botanists who have identified *A. volubilis* in India also confirm that the Sri Lankan specimens in question do not possess the diagnostic characteristics of *A. volubilis* (P. L. Hettiarachchi, pers. comm., 1997). Rather, in some instances we were dealing with an ambiguity between *A. ilicifolius* and *A. ebracteatus* Vahl. in Pambala. It must, however, be stressed that a large plasticity exists between the members of this genus Tomlinson, 1986).

In addition to Rao (1987), Liyanage (1997) also reported the presence of *Avicennia alba* in Sri Lanka. However, unlike Rao (1987) who included the species in his list of mangrove species without further details, Liyanage (1997) gave a description and localities of the species with a technical drawing (Fig. 2). The description, however, is not precise enough to distinguish *A. alba* from the other two *Avicennia* species that occur in Sri Lanka. In the present study, the localities given by Liyanage (Puttalam and Seenimodara) were revisited but *A. alba* was not found there, or indeed anywhere else. If *A. alba* had been present, it would have been easily recognizable because of its elongated and pointed propagules (see previous section). The inclusion of *A. alba* by Liyanage (1997) in the list of mangrove species occurring in Sri Lanka appears to be based on a specimen represented by a copy of the drawing given by Arulchelvam (1968) to illustrate *Avicennia officinalis* (but with slight alterations to the leaf tips), and therefore should be strongly rejected (Fig. 2).

Ceriops decandra (Griff.) Ding Hou was reported as a mangrove species in Sri Lanka by a few authors without giving a description or locality. Macnae & Fosberg (1981a,b) also state that they have not observed this species in Sri Lanka. Nevertheless,

A. officinalis (Arulchelvam, 1968) *A. alba* (Liyanage, 1997)

Figure 2. Example of the erroneous listing of species in Sri Lanka: the report of *Avicennia alba* (Liyanage, 1997), based on an original drawing of *Avicennia officinalis* (Arulchelvam, 1968).

Liyanage (1997) lists Rekawa Lagoon (Fig. 1, Table 1) and he gives a description, an illustration and a locality. However, over 15 years our joint research experience at this lagoon (Jayatissa, 1987; Thomaes, 1996; Verheyden *et al.* in press) has lead only to the identification of *C. tagal* (Perr.) C.B. Robinson within this genus. Similar to the previous case, Liyanage (1997) apparently based his drawing on the photograph of *C. tagal* given in the same publication (Liyanage, 1997), but with slight changes to the propagule root apex, the major characteristic for identification of *C. decandra*. The description given to illustrate this species does not correspond with the actual description of the species by Tomlinson (1986).

Sonneratia ovata Backer and *Sonneratia griffithii* Kurz were not recorded in the present study, but were reported by Liyanage (1997) as Sri Lankan mangrove species. The former species was reported as a very rare species observed in Negombo lagoon. According to Tomlinson (1986), *S. ovata* is distinguished by a finely warted calyx, which forms a cup enclosing the base of the fruit, and a fruit apex that is depressed at the base of the style. Liyanage (1997) used the characteristic of the cup-shaped calyx in fruits with a depression at the base of the style to distinguish *S. ovata*, but neither a photograph nor a drawing was given for this feature. Not only is it important to note that according to Tomlinson (1986) the cup-shaped calyx is a common character for *S. alba* as well, but even more important is the fact that in their revision of the *Sonneratia* genus, Duke & Jackes (1987) identified the cup-shaped fruit receptacle as a means to differentiate *S. alba* and S. × *gulngai* from the other members of the genus (including *S. ovata*), the latter of which have flattened fruit receptacles. The isolated tree in Negombo lagoon, given in Liyanage (1997) as one of the few locations for *S. ovata*, was visited in the present study and identified as *S. alba*, based on the cup-shaped calyx, on the white petals and on our experience in Kenya.

According to Tomlinson (1986) and Banerjee *et al.* (1989), obovate or suborbicular leaves with conspicuous veins, prominent on the adaxial side, and scarcely developed petioles are some of the characteristics that help to distinguish *S. griffithii* from other *Sonneratia* species. The description and photograph given in Liyanage (1997) for *S. griffithii* suggest that veins are not conspicuous and that petioles are well developed. Another fact stated by Liyanage (1997) is that *S. griffithii* produces pencil-like pneumatophores, commonly found in *Avicennia* species. The photograph in this paper does indeed show pencil-like pneumatophores on the ground surrounding a *Sonneratia* tree (including its own peg roots), but the author failed to recognize that these roots originate from the *Avicennia* trees located on the background of the photograph. Therefore, it is clear that the inclusion of both *S. griffithii* and *S. ovata* by Liyanage (1997) is the result of a misidentification.

The mangrove associate *Acrostichum speciosum* Willd. was also reported by Liyanage (1997) as a very rare plant recorded only from the Hikkaduwa and Akurala mangrove communities. However, again upon visiting the stated communities this study failed to record the species. Neither was it observed elsewhere. The drawing given for *A. speciosum* in Liyanage (1997) is similar to the illustration of *A. aureum* and does not distinguish it from the latter species.

Consequences of erroneous species lists for the study of mangroves

The shortcomings of certain national publications mentioned above are extremely important for the scientific community because of their impact on the quality of available information. Usually scientists seeking information on the distribution of plants in a given country are directed to its Forest Department or other governmental body. If the information of such institutions is subject to misidentifications (whether it be intentional or unintentional), leading for example to exaggerated claims of mangrove biodiversity, this clearly degrades the quality of information available for dissemination.

In a biogeographic research framework, the consequences of the interpretation of such erroneous data can hardly be over stated. Although, for some species, an erroneous presence in Sri Lanka has little influence on their global biogeographical extent, as for instance is the case with *Ceriops decandra* (Liyanage, 1997) or *Kandelia candel* (Rao, 1987). The latter, for instance, is also present in the Ganges Delta according to Tomlinson (1986) and along about 80% of the Indian coast according to Spalding *et al.* (1997). But for reports of *Sonneratia ovata* or *S. griffithii* (Liyanage, 1997), the impact is far greater and would mean a disjunct global distribution pattern with Sri Lanka as a distant outlier. This of course depends on the scale at which this problem is analysed. Adopting the wide biogeographical regions used by Duke (1992) and Duke *et al.* (1998), there is only a minor difference in the distribution of the said *Sonneratia* species with or without Sri Lanka as a point of occurrence, because both species occur within the Indo-Malaysian region, while *S. ovata* also occurs within Australasia. However, on a smaller scale – but larger than the estuarine scale, hierarchically the next scale in the series of scales used by Duke et al. (1998) to discuss the distribution gradients of mangroves – there are striking implications. Figure 3, which is based on Spalding *et al.* (1997), shows that *S. ovata* has a distribution from Thailand through the Malay Peninsula and Malay

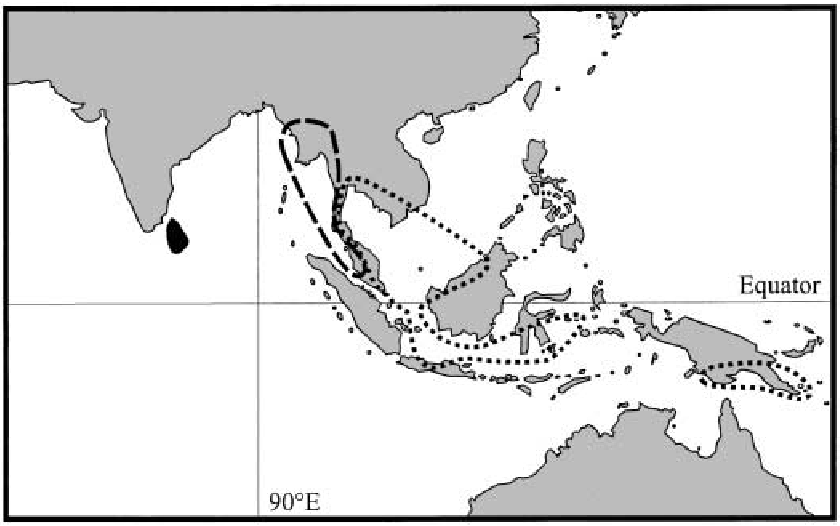

Figure 3. Distribution of *Sonneratia ovata* (dotted line) and *S. griffithii* (dashed line) in relation to the location of Sri Lanka (shaded black) according to Spalding *et al.* (1997).

Archipelago (excluding Borneo) to the Gulf of Papua in New Guinea and into Queensland, whereas *S. griffithii* is restricted to the Andaman Sea, from the upper Malay Peninsula to Bengal. For both species, the record in Sri Lanka is relatively far outside their known biogeographical range. Similar discussions can be had for *Bruguiera hainesii* and *B. parviflora*, which are reported for Sri Lanka (Spalding *et al.*, 1997).

The publication of erroneous data about species composition also has implications for the remote sensing of inaccessible or formerly uninvestigated mangrove areas. Given the continuing unstable political situation in Sri Lanka, remotely sensed mangrove data from lagoons located within inaccessible parts of the country are likely to be used in the future. Verheyden *et al.* (in press) proposed identification keys for aerial photographs from three mangrove lagoons in Sri Lanka. Theoretically, extrapolation of these finding to other lagoons is possible, although any such classification must be viewed as preliminary and fieldwork for verification purposes is essential. Erroneous species records for these three lagoons can easily lead to wrong interpretations being made elsewhere. For instance, the report of *Avicennia marina* or *A. officinalis*, which has a light grey or white tone on aerial photographs, in a lagoon where in reality this genus is poorly represented (e.g. *A. alba* for Puttalam Lagoon by Liyanage, 1997), may lead to confusion with other species with a similar tone, such as the widespread species *Excoecaria agallocha*.

Related to the previous discussion is the use of data on species composition for issues such as conservation biology. Forests with different species compositions may require very specific management practices, particularly if rare species are involved. For example, a mangrove stand dominated by *E. agallocha*, a species that can resist human disturbance on decadal scales (Dahdouh-Guebas *et al.*, 2000a), probably requires a less strict management than a stand dominated by highly vulnerable mangrove species. Mangrove plants species also extend over a large range of environmental conditions, some of which may suit a particular species, but be fatal to another. Factors that may be decisive in the success or failure of mangrove rehabilitation measures are, for instance, hydrology (Elster, 2000), salinity (Elster, 2000) or propagule predation (Dahdouh-Guebas *et al.*, 1997, 1998; Dahdouh-Guebas, 2001). Prioritization of resource allocation for conservation may also be hampered by incorrect species composition reports. In this regard, Cormier-Salem (1999) also emphasized that the definition of 'mangrove species' is not solely an academic debate, but has political and social implications as well. Apart from the definition of a mangrove in the context of species, she highlights the variability of 'mangrove area' delimitation, which can be defined in a floristic, a faunistic or a human context.

In a country like Sri Lanka (the south-western part), where the actual distribution of the mangrove communities is the result of increased human-induced fragmentation (De Silva & Balasubramaniam, 1984–85), and where each mangrove community has been easily accessible for a long time (Jayewardene, 1985), there is a significant positive relationship between national reports of mangrove species totals and the recency of the report. Such a paradoxical situation in these accessible areas can be explained by the national prestige associated with the discovery of additional species. In addition, there seems to be an international competition, particularly amongst certain researchers from developing countries, to report more and more mangrove species, and in this way impose a certain type of respect for their country's national mangrove communities. In this context, the inclusion of mangrove associates or beach vegetation, which occurs occasionally within the mangrove, when reporting the total number of 'mangrove species' is a common trend.

Another problem is the reluctance of some senior scientists to perform fieldwork (pers. observ.), particularly within the 'inhospitable' mangrove ecosystem, instead preferring to work with field officers. Double-checking is rarely, if ever, performed and, if it is, it is restricted to a distant visual inspection from dry land or from a boat.

The above lacunas are the main causes of the publication of erroneous lists of mangrove species. This is very regrettable because, particularly for developing countries, this leads to a general underestimation of the scientific capabilities of the institutes involved, and the quality of some of the rigorous research papers (e.g. Abeywickrema, 1960; Pemadasa, 1997; De Silva & Balasubramaniam, 1984–85; or the Revised Series of the Flora of Ceylon) may be undermined. In addition, investigations on floristics and species composition are one of the few studies that developing countries can partake in because of the relative ease and inexpense at which they can be carried out; this should not be compromised.

CONCLUSION

The present study is intended to provide an objective and realistic revision of the mangrove species present in Sri Lanka, or at least its south-western part, and to review and highlight the causes of misidentifications of Sri Lankan mangroves in the past. This study therefore required a standardization of fieldwork and that identifications made by different persons be double-checked over the 4-year period of the study using the existing diagnostic identification keys, herbaria and the Indo–East African field knowledge of the survey team. The use of photographs to illustrate the 20 Sri Lankan mangrove species reported in this study was considered beyond the scope of this paper, but Appendix 1 provides details on the locations of each species reported.

Three mangrove species (*Lumnitzera littorea*, *Pemphis acidula* Forst. and *Scyphiphora hydrophyllacea*), one mangrove associate (*Cynometra iripa*) and one species of beach vegetation communities (*Xylocarpus rumphii*) were found by this study to be very rare (Table 1); their distribution is restricted to a few trees at one or two localities in Sri Lanka. In addition to these very rare species, another three species of true mangroves (*Bruguiera cylindrica*, *Excoecaria indica* and *Sonneratia alba*) were found to be rare. At present, all these species are at serious risk as no systematic attempt has been made to conserve them, nor to educate the local people about their significance or to draw attention to their value and current situation (cf. activities of the Small Fishers Federation of Lanka). For instance, the conversion of mangrove forests for aquaculture (Dahdouh-Guebas *et al.*, 2000) and the pollution of mangrove ecosystems continues unchecked (Foell *et al.*, 1999), and indicates that many mangroves are 'outlaws'. Therefore, we close this review by emphasizing the need for urgent and concerted efforts to conserve Sri Lankan mangrove ecosystems *in situ*.

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APPENDIX 1: DISTRIBUTION OF MANGROVE SPECIES IN SOUTH-WESTERN SRI LANKA

The 43 mangrove sites visited (Fig. 1) are numbered as follows (in geographical order):

1. Palatupana L.	23. Goiyyapana
2. Kirinda L.	24. Koggala L.
3. Embilikala L.	25. Timbiri Ela
4. Hambantota lewaya inlet	26. Galle-Unawatuna
5. Walawey Ganga E.	27. Ginganga E.
6. Lunama L.	28. Ratgama Oya
7. Kalametiya L.	29. Hikkaduwa
8. Tillawatawana L.	30. Akurala
9. Rekawa L.	31. Madampa Ganga
10. Kirama Oya mouth	32. Balapitiya
11. Seenimodara canal mouth	33. Kosgoda
12. Mawella L.	34. Bentota Ganga E.
13. Kataketiya	35. Kaluwamodara
14. Dickwella	36. Maggona
15. Tondilay L.	37. Kalu Ganga E.
16. Suduwella	38. Moratuwa Ganga E.
17. Talalla	39. Negombo L.
18. Devinuwara L.	40. Gin Oya
19. Nilwala Ganga E.	41. Pambala-Chilaw L.
20. Garanduwa L.	42. Mundel Lake
21. Polwatumodara	43. Puttalam L.
22. Kapparatota	

Sinhala: Ganga = river; Ela = stream; Oya = large stream; L. = lagoon; E. = estuary

In the present study, the 20 mangrove species present between Palatupana and Puttalam (Table 1) were observed in the following sites (numbers correspond to the table above):

Aegiceras corniculatum (L.) Blanco: (5), (8) (9), (18), (20), (26), (33), (39), (41), (43)
Avicennia marina (Forsk.) Vierh.: (7–9), (12), (18), (26), (39–43)
Avicennia officinalis L.: (4), (9–11), (13), (14), (17), (18), (39), (41)
Bruguiera cylindrica (L.) Blume: (39), (41), (43)
Bruguiera gymnorrhiza (L.) Lamk.: (8–10), (18), (24), (26), (32), (34), (35), (38), (39), (41)
Bruguiera sexangula (Lour.) Poir.: (8–11), (13–41)
Ceriops tagal (Perr.) C.B. Robinson: (9), (39), (41), (43)
Excoecaria agallocha L.: (5–21), (23), (26–35), (39–43)
Excoecaria indica (Willd.) Muell.-Arg. / *Sapium indicum* Willd.: (8), (34), (40–41)
Heritiera littoralis Dryand.: (8–10), (13), (14), (24), (26), (29), (31), (34), (35), (39–41)
Lumnitzera littorea (Jack) Voigt: (32)
Lumnitzera racemosa Willd.: (1), (2), (4), (6–9), (11), (15), (18), (24), (26), (30), (32), (39), (41–43)
Nypa fruticans (Thunb.) Wurmb.: (8–10), (14), (17), (18), (19), (21), (29), (31), (32), (36), (40)
Pemphis acidula Forst.: (26), (43)
Rhizophora apiculata BL.: (14), (18), (19), (21), (24), (26–29), (31–35), (38–39), (41)
Rhizophora mucronata Lamk.: (8–10), (24), (39–41), (43)
Scyphiphora hydrophyllacea Gaertn.f.: (43)
Sonneratia alba J. Smith: (39), (41), (43)
Sonneratia caseolaris (L.) Engler: (5), (7), (8), (10–12), (14), (16–24), (26), (27), (29), (30), (34), (36–41)
Xylocarpus granatum König: (21), (41)