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Status, diversity and conservation of the mangrove forests of Sri Lanka

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Abstract

In Sri Lanka, mangrove forests are found scattered mainly along the north-western, north-eastern and eastern coasts bordering lagoons and river estuaries. The area covered by the mangrove forests today is estimated as only 87 km^2 (Legg & Jewell, 1995). Most of the mangrove forest areas have been subjected to human interference for a long time, and undisturbed mangrove forests are seldom found. In most areas, the mangrove forests are usually restricted to a narrow strip, sometimes only a few trees deep. The largest mangrove forest, which is in the Kala Oya estuary, is not more than 0.5 km deep and extends upstream about 2 km from the river mouth. The low level of tidal fluctuations is mainly responsible for the narrowness of the mangrove forests as only a small area comes under the tidal influence. A clear zonation is not seen in most localities because of the narrowness of the mangrove forest and the human interference. Two major kinds of mangrove forests, namely, low-saline and high-saline, could be distinguished by the floristic composition; three other specialised high saline types, scrub, overwash, and basin, are also sometimes distinguished depending on the flooding characteristics and topography. Twenty three true mangrove species of trees and shrubs have been recorded in Sri Lanka, the common species being *Rhizophora mucronata, Avicennia marina, Excoecaria agallocha, Acanthus ilicifolius, Lumnitzera racemosa, Sonneratia caseolaris, Bruguiera gymnorhiza* and *Aegiceras corniculatum*. The rare species are *Ceriops decandra, Sonneratia apetala, Lumnitzera littorea, Scyphiphora hydrophyllacea* and *Cynometra iripa*, of which the first three are endangered species in Sri Lanka. In general, the aquatic fauna, especially fish, is estuarine fauna. *Cerithidea cingulata* and *Terebralia palustris* (Gastropoda) are very common. The latter species as well as grapsid crabs, fiddler crabs and the mud-lobster (*Thalassina anomala*) are usually not found outside mangrove areas. Of the vertebrate fauna, avifauna is the most abundant and a variety of wading birds use mangrove-associated estuaries and lagoons for feeding and mangrove trees for roosting and nesting. Strict conservation measures are urgently required, especially in the face of the increased destruction of mangrove forests in recent years for the construction of prawn culture ponds.

Keywords: mangroves, mangals, tidal forests, tropical, intertidal, estuarine, lagoon, brackish-water.

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Introduction

Mangrove forests (which have also been referred to as mangals, intertidal forests and coastal woodlands by various authors (Saenger, 1983)) constitute a characteristic coastal ecosystem of evergreen woody plants in the tropical and subtropical areas of the world. The total area of mangrove forests in the world is estimated as over 150,000 km^2, of which over 62,000 km^2 are in tropical Asia (Aksornkoae, 1985). Mangrove forests in Sri Lanka are found scattered mainly along the northern, north-eastern and eastern coasts bordering lagoons and river estuaries. The area covered by the mangrove ecosystem today is estimated as only 87 km^2 (Legg & Jewell, 1995) (60-130 km^2 according to Baldwin, 1991) as opposed to much larger areas of mangrove forest areas found in other tropical Asian countries, especially in the south-eastern region (e.g. India - 3,565 km^2; Bangladesh - 4,050 km^2; Burma - 5,171 km^2; Thailand - 1,634 km^2; Malaysia - 6,522 km^2; Indonesia - 21, 763 km^2 (Saenger, *et al.*, 1983)). Sri Lankan mangrove forests cover only about 0.1-0.2 % of the total land area of the island (66,166 km^2 according to Legg & Jewell, 1995) but they are found in many lagoons and river estuaries. Most of the mangrove areas have been subjected to human interference for a long time, and therefore, undisturbed mangrove forests are rare.

Sri Lankan mangrove forests have been studied by several workers from 1960s (Abeywickrama, 1964; Arulchelvam, 1968; Balasubramaniam *et al.*, 1970; Pinto, 1982; Balasubramaniam, 1985; de Silva & Balasubramaniam, 1985; de Silva & de Silva, 1987; Amarasinghe & Balasubramaniam, 1992). Although mangrove forests are present in association with most of the estuaries, the west coast mangrove forests have been more thoroughly studied than the others.

This paper is based mainly on the studies of the present authors of the mangrove forests in west, south and east coasts during 1985-88 and 1993-95. The data on the mangrove forests in Trincomalee (Mahaweli estuary), Jaffna lagoon and Vadamarachchi lagoon were provided by S. Balasubramaniam (pers. comm.) during the period 1984/85. These data as well as those on the mangrove forests from Mannar to Kala Oya estuary could not be updated because of continuing acts of terrorism in these regions.

Materials and methods

During the study period the mangrove forests on the shores of mainland and islands in estuaries and lagoons from Mannar in the north-west to the river Kumbukkan Oya in the south-east and Batticaloa lagoon (Fig. 1) were studied. In each mangrove forest, the floral composition, zonation and the fauna were studied in 5 m belt transects, at least three transects in each mangrove forest, taken at right angles from the edge of water to the inland edge. In the mangrove forests which were very narrow (i.e. only a few trees deep), three 100 m lengths along the shoreline were studied. Human interference was assessed on a scale of 0 (less than 1% of the mangrove forests affected) to 5 (over 90% of the mangrove forest affected).

Lagoons and estuaries. Pritchard (1967) defines an estuary as "a semi-enclosed coastal body of water, which has a free connection with the open sea, and within which sea water is measurably diluted with freshwater derived from

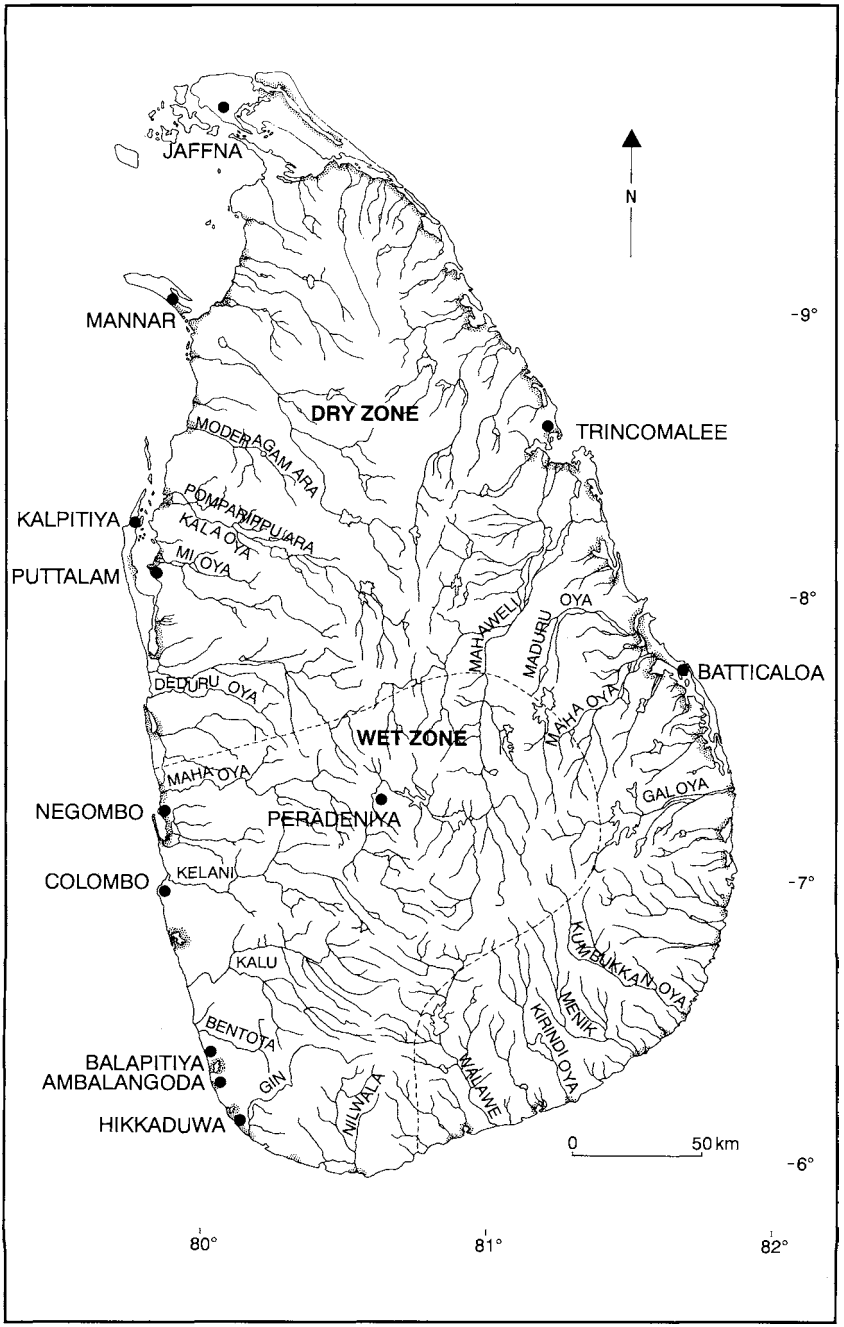

Figure 1. Distribution of mangrove forests in Sri Lanka. Mnagroves area are shaded, and have been exaggerated for clarity.

land drainage". Thus, an estuary is subjected to the influence of regular tidal fluctuations. On the other hand, a lagoon does not normally have a free connection with the open sea and may be inundated with sea water at irregular intervals only; it receives freshwater mainly from direct rainfall rather than from land drainage (e.g. a lagoon within an atoll). According to these definitions, all so-called lagoons in Sri Lanka must properly be categorised as estuaries. However, in the present work, for convenience of reference to maps and earlier literature, the customary usage of terms is retained; i.e. a lagoon is considered to be a stretch of salt water separated by a low sand bank from the sea or connected with the latter by a narrow passage; and an estuary is the tidal mouth of a river.

Observations

Extent and distribution of mangrove forests. Mangrove forests in Sri Lanka are not extensive and are often limited to narrow strips, sometimes only a few trees deep. At present, mangrove forests are present in patches in association with the estuaries and lagoons. The largest mangrove forest occurs in the Kalpitiya lagoon region (including Dutch bay and Portuguese bay) in the north-west (Fig. 1) and has been estimated as 33.9 km^2 (Baldwin, 1991). Kala Oya-Pomparippu Ara mangrove forest, the largest within this area, has been estimated as 18.4 km^2 by the analysis of aerial photographs (Kanakaratne *et al.*, 1984), but one-inch topographic map of the area based on ground surveys shows much less mangrove forests. The Kala Oya mangrove forest is not more than 0.5 km deep and extends about 2 km upstream from the river mouth.

In Sri Lanka, the climatic conditions depend mainly on the distribution of rainfall, the seasonal changes in temperature being slight. On the amount of rainfall received the island could be divided into a "Wet Zone" in the south-west quarter (Fig. 1) (with an annual rainfall of >2000 mm distributed rather evenly throughout the year) and a "Dry Zone" covering the rest of the country (with an annual rainfall of 1,000-2,000 mm and with a marked dry season, which lasts several months). Thus, the freshwater discharge in the wet zone is much higher and occurs throughout the year, whereas that in the dry zone is much less and occurs more or less seasonally. These climatic characteristics influence the development of the mangrove forests in the two zones (sometimes, two "Semi-arid" zones in the north-west and south-east and an "Intermediate zone" at the boundary of dry and wet zones are recognised, but, this division is not important as far as the floral composition of the mangrove forests are considered, and hence disregarded in this study).

The distribution of mangrove forests in Sri Lanka is shown in Fig. 1.

Physico-chemical characteristics. The average air temperatures prevailing in the mangrove forests range from about 30°C to 35°C. The relative humidity is very high and ranges from 80%->90%. The salinity in mangrove waters could vary from almost nil to more than that of sea water. The lagoons and estuaries contain alluvial deposits and the soil consists mainly of silt and fine clay, although in some areas sandy soil is found. The soil is waterlogged, and consequently poorly aerated; in some locations there is stagnant water. Salinity depends mainly on the pattern and amount of freshwater discharge from

Table 1. Some physico-chemical characteristics of water in selected mangrove forests. (dO_2-dissolved oxygen concentration; WZ-wet zone; DZ-dry zone; HS-high-saline; LS-low-saline; SC-scrub).

Characteristic♦ Mangrove forest/	Climatic zone	Mangrove type	Temp. ºC	pH	dO_2 ppm	Salinity ppt
Negombo	WZ	HS/LS	27-31	7.5-8.3	4.6-8.7	18 - 32
Bentota	WZ	LS	26-30	6.1-7.2	5.1-8.8	0 - 8
Balapitiya	WZ	LS	26-31	6.4-7.6	4.1-8.1	0 - 6
Koggala	WZ	LS	27-32	6.6-8.2	4.5-9.2	0 - 12
Rekawa	WZ	HS	29-34	6.2-7.4	6.3-10.6	18 - 34
Ranna Oya	WZ	LS	28-32	6.2-7.3	5.2-8.3	3 - 9
Kalametiya-Lunama	DZ	LS	28-32	7.5-9.2	4.0-8.5	0 - 6
Menik river	DZ	HS	27-33	7.1-8.3	4.1-7.9	0 - 26
Kumbukkan Oya	DZ	LS	27-33	7.1-8.2	4.3-8.0	0 - 18
Batticaloa	DZ	HS	27-34	6.9-8.3	3.9-7.8	6 - 34
Mannar	DZ	HS	28-42	6.9-7.9	3.1-7.5	21 - 36
Kalpitiya	DZ	HS	28-41	7.3-8.2	3.1-8.1	21 - 36
Kala Oya	DZ	HS/LS	27-31	7.1-8.1	3.5-7.4	0 - 28
Mi Oya	DZ	HS/LS	27-31	6.9-8.1	4.1-8.3	0 - 25
Mundel	DZ	SC	27-35	7.1-8.4	4.5-9.1	15 - 45

nearby rivers, the tidal amplitude, and the topography and the extent of the estuary or lagoon.

Some important physico-chemical characteristics of water in selected mangrove forests are given in Table 1.

Mangrove macroflora

Twenty three species of true-mangrove trees and shrubs have been recorded in Sri Lanka (Table 2). (S. Liyanage (pers. comm.) recorded *Sonneratia griffithii, S. ovata, Avicennia alba* (= *A. marina,* vide Moldenke & Moldenke, 1983), *Acanthus volubilis* and *Xylocarpus mekongensis* from the mangroves in western and southern coasts; however, no voucher specimens were available for examination.) Depending on the region, several species of sea grasses are found in the fore-mangrove, and a variety of freshwater-marsh, salt-marsh, or sea shore plants are found in the back-mangrove. The sea grass beds are common in shallow seas in larger lagoons such as those in Kalpitiya, Batticaloa and Jaffna. The common true mangrove species are: *Rhizophora mucronata, Avicennia marina, Excoecaria agallocha, Acanthus ilicifolius, Lumnitzera racemosa, Sonneratia caseolaris, Bruguiera gymnorhiza* and *Aegiceras corniculatum.* These trees are short in comparison to those found in other Asian countries such as Indonesia, Malaysia and Thailand. The tallest trees which grow to about 15 m are found in the Kala Oya and Kalpitiya mangrove forests (Fig. 1) and a few trees growing to about 15-20 m are found in Kaluwamodera in the south and Batticaloa in the east; trees in other mangrove forests are usually shorter than 10 m.

Five mangrove species appear to be rather rare: *Ceriops decandra* (recorded in a single mangrove forest), *Sonneratia apetala* (single forest), *Lumnitzera littorea* (two forests), *Scyphiphora hydrophyllacea* (three forests), *Cynometra iripa* (three forests) (see Discussion). Of these, the first three species can be considered to be endangered. *Lumnitzera littorea* is observed in the wet zone whereas the other four are recorded from the dry zone.

Table 2. Important species of true mangrove trees and shrubs and mangrove associates of Sri Lanka.

True mangrove species

Acanthaceae
Acanthus ilicifolius L.
Arecaceae (Palmae)
Nypa fruticans Wurmb.
Avicenniaceae
Avicennia marina (Forsk.) Vierh.
A. officinalis L.
Combretaceae
Lumnitzera littorea (Jack) Voigt
L. racemosa Willd.
Euphorbiaceae
Excoecaria agallocha L.
Fabaceae (Leguminosae)
Cynometra iripa Kostel.
Meliaceae
Xylocarpus granatum Koenig
X. rumphii (Kostel.) Mabb.
Myrsinaceae
Aegiceras corniculatum (L.) Blanco
Rhizophoraceae
Bruguiera cylindrica (L.) Blume
B. gymnorhiza (L.) Savigny
B. sexangula (Lour.) Poir.
Ceriops decandra (Griff.) Ding Hou
C. tagal (Perr.) C.B.Rob.
Rhizophora apiculata Blume
R. mucronata Poir.
Rubiaceae
Scyphiphora hydrophyllacea Gaertn.f.
Sonneratiaceae
Sonnaratia alba J. Smith
S. apetala Buch.-Ham.
S. caseolaris (L.) Engler
Sterculiaceae
Heritiera littoralis Dryand.

Mangrove Associates

(Fore Mangrove - Sea grasses)
Cymodoceaceae
Cymodocea serrulata (R. Br.) Aschers & Magnus
Halodule uninervis (Forssk.) Aschers (=*Diplanthera uninervis* (Forssk.) Aeschers)
Syringodium isoetifolium (Aschers) Dandy
Hydrocharitaceae
Enhalus acoroides (L.f.) Royle
Halophila decipiens Ostenf.
H. ovalis (R. Br.) Hook. f.
Thalassia hemprichii (Ehrenb.) Asschers
Najadaceae
Najas graminea Del.
N. marina L.
Potamogetonaceae
Potamogeton pectinatus L.
Ruppia maritima L.

(Back Mangrove)
Aizoaceae
Sesuvium portulacastrum (L.) L.
Annonaceae
Annona glabra L.
Apocynaceae
Cerbera odollam Gaertn.
Ochrosia oppositifolia (Lam.) K.Schum.
Arecaceae (Palmae)
Cocos nucifera L.
Asteraceae (Compositae)
Sphaeranthus amaranthoides Burmf.
S. africanus L.
S. indicus L.
Bignoniaceae
Dolichandrone spathacea (L.f.) K.Schum.
Chenopodiaceae
Arthrocnemum indicum (Willd.)Moq.
Salicornia brachiata Roxb.
Suaeda maritima (L.) Dumort.
S. monoica Forssk. ex J.F. Gmel.
S. nudiflora (Willd.) Moq.
Clusiaceae (Guttiferae)
Calophyllum inophyllum L.
Cyperaceae
Cyperus rotundus L.
Fimbristylis ferruginea (L.) Vahl
Schoenoplectus littoralis (Schrad.) Palla
Fabaceae (Leguminosae)
Aganope heptaphylla (L.) Polhill
Dalbergia candenatensis (Dennst.) Prain
Derris heterophylla Willd.
Pongamia pinnata (L.) Pierre
Hernandiaceae
Hernandia nymphaeifolia (Presl) Kubitzki
Lecythidaceae
Barringtonia asiatica (L.) Kurz
B. racemosa (L.) Sprengel
Lythraceae
Pemphis acidula J.R. & G. Forst.
Malvaceae
Hibiscus tiliaceus L.
Thespesia populnea (L.) Solander ex Correa
Myrsinaceae
Ardisia elliptica Thunb.
Pandanaceae
Pandanus odoratissimus L.f.
Poaceae (Gramineae)
Zoysia matrella (L.) Merrill
Tamaricaceae
Tamarix indica Willd.
Verbenaceae
Clerodendrum inerme (L.) Gaertn
Premna obtusifolia R. Br.

HEMIPARASITES ON TRUE MANGROVE SPECIES
Loranthaceae
Dendrophthoe falcata (L.f.) Ethingsh on *Aegiceras corniculatum*
Viscaceae
Viscum orientale Willd. on *Excoecaria agallocha*

PTERYDOPHYTA (FERNS)
Adiantacea
Acrostichum aureum L.

A variety of trees and shrubs grows in the back mangrove (Table 1) of which the important species are: *Acrostichum aureum, Ardisia elliptica, Barringtonia racemosa, Cerbera odollam, Clerodendrum inermae, Dolichandrone spathacea, Hibiscus tiliaceus, Pemphis acidula* and *Thespesia populnea*. (S. Liyanage (pers. comm.) additionally recorded *Acrostichum speciosum*). Sometimes, species of thorn forest and dry evergreen forest (in the dry zone) and species of wet evergreen forest (in the wet zone) are also seen intermingled in the mangrove forests.

In general, many true mangrove species (see below) are commonly found in all sites, but the floristic composition of the dry zone mangrove forests is somewhat different from that of the wet zone mangrove forests. Because of the seasonality of rains and the lower freshwater discharge in the dry zone (Table 3), the mangrove forests in this zone experience higher salinity as opposed to those in the wet zone which experience much higher and evenly distributed annual rainfall and freshwater discharge and therefore lower salinity. *Nypa fruticans* is found only in the wet zone. Its range extends from the estuary of Ranna Oya to the estuary of Gin Oya, a tributary of Maha Oya (Fig. 1). *Rhizophora mucronata* is more common in the dry zone whereas *R. apiculata* is more common in the wet zone. *Bruguiera sexangula* is more common in the wet zone whereas *B. cylindrica* is more common in the dry zone. The differences in the floristic compositions reflect the salinity tolerances of individual species. The dry zone mangrove forests often have saltmarsh plants such as *Arthrocnemum indicum, Salicornia brachiata* and *Suaeda* spp. in the back mangrove whereas wet zone mangrove forests have mangrove associates such as *Dolichandrone spathacea*.

The distribution of mangrove plants in some selected mangrove forests is shown in Table 4, and that of different regions and the status of each species are shown in Table 5.

The usual zonation of trees, observed in the mangrove forests of other countries such as Indonesia, Malaysia and Thailand, is not well marked in Sri Lanka. Generally, in larger mangrove forests, there is a zone of *Rhizophora, Sonneratia*, and *Bruguiera* at the waterfront, with *Rhizophora* usually occupying the lowest position, followed by a mixed mangrove community of other true mangrove species such as *Aegiceras corniculatum, Ceriops tagal* and *Lumnitzera racemosa*. *Avicennia marina* is found in the mixed zone, usually towards the inland margin, but may extend to edge of water as well. In smaller and narrow mangrove forests as well as in those that have been much affected by human interference this zonation is disturbed and all species may occur inter-mixed.

Mangrove forest types. Based on floral characteristics, we recognise two broad mangrove forest types in Sri Lanka, 'low-saline' and 'high-saline'. 'Low-saline' mangrove forests are usually present in the river estuaries whereas the 'high-saline' kind is usually present on the shores of lagoons and islands within lagoons. However, in the dry zone, sometimes along the same river, a high-saline mangrove forest is present at the river mouth, gradually changing into a low-saline forest further upstream. This is also true of long lagoons in which a river opens in the upstream area of the lagoon. Here, the area around the lagoon mouth contains high-saline mangrove forest, gradually changing into a low-saline one in the proximity of the freshwater source. In some others, especially

Table 3. Number of rivers and their annual discharge, length of shoreline and the discharge per kilometre of shoreline of the dry zone and wet zone.

Zone	No. of rivers	Annual discharge, A (10^6 cubic metres)	Shoreline, B (km)	A/B
Wet Zone	17	29,457	270	109.10
Dry Zone	86	26,824	1430	18.76

when the mangrove forest is very small, a mixture of both vegetation types is present.

LOW SALINE MANGROVE FORESTS. These are found in the river estuaries and lagoons where salinity is low, often below 10 ppt, and more importantly, where this low salinity prevails throughout or during most of the year. Low-saline mangrove forests usually show a more luxuriant growth than the high-saline ones. Communities of *Nypa fruticans, Sonneratia caseolaris, Bruguiera sexangula* and *Rhizophora apiculata* as well as the mangrove-associates such as *Dolichandrone spathacea* and *Annona glabra* are characteristic of the low-saline type. An estuary or lagoon associated with a low-saline mangrove forest usually contains communities of freshwater phytoplankton, zooplankton, macrophytes and macrofauna.

HIGH SALINE MANGROVE FORESTS. High-saline mangrove forests are usually associated with lagoons and estuaries in which the salinity is in excess of 25 ppt at least during a part of the year. They are usually characterised by the presence of *Rhizophora mucronata* and *Avicennia marina,* but *Acanthus ilicifolius, Aegiceras corniculatum* and *Excoecaria agallocha* are also common. The lagoons and estuaries with associated high-saline mangrove forests usually contain marine plankton and sea grasses. The back-mangrove contains species such as *Ardisia elliptica, Premna obtusifolia,* and *Pemphis acidula,* and in drier regions where salinity is very high, salt marsh plants are often present in the back mangrove.

Three other types of mangrove forests, namely, scrub, overwash and basin, have been described in Sri Lanka on the basis of flooding and topographical characteristics (Balasubramaniam, 1985), and these appear to be specialised instances of the high saline type.

SCRUB MANGROVE FORESTS. The scrub mangrove forests are degraded mangrove forests and develop in areas of poor drainage which often become waterlogged. They are covered only during extreme high tides and during occasional rains. The soil tends to get hypersaline during the dry season. The scrub mangrove forests are characterised by greatly stunted trees and are therefore sometimes referred to as dwarf mangrove forests. *Avicennia marina* is the dominant species, but *Excoecaria agallocha* and sometimes *Lumnitzera racemosa* and *Aegiceras corniculatum* are also found. Species prominent in other mangrove forests such as *Rhizophora, Bruguiera* and *Sonneratia* are usually absent. Saltmarsh plants such as *Arthrocnemum indicum, Salicornia brachiata* and *Suaeda* spp. are common and well developed, and often grow intermixed with the mangrove trees. Such degraded scrub mangrove forests are occasionally seen in the dry zone

Table 4. The distribution of common mangrove species in different mangrove forests. (AC- *Aegiceras corniculatum;* AI- *Acanthus ilicifolius;* AM- *Avicennia marina;* AO-*A. officinalis ;* BC- *Bruguiera cylindrica;* BG- *B. gymnorhiza;* BS- *B. sexangula;* CT- *Ceriops tagal;* EA- *Excoecaria agallocha;* HL- *Heritiera littoralis;* LR- *Lumnitzera racemosa;* NF-*Nypa fruticans ;* RA- *Rhizophora apiculata;* RM- *R. mucronata;* SA- *Sonneratia alba;* SC- *S. caseolaris;* XG-*Xylopcarpus granatum;* XR-*X. rumphii* (*** >50%, ** 25-50%, * 10-25%, +++ 5-10%, ++ 1-5%l, + <1%, — not observed) ; HI-Degree of human interference (0—<1%; 1—1-10%; 2—10-25%; 3—25-50%; 4—50-90%; 5—>90% affected).

Mangrove forest	AC	AI	AM	AO	BC	BG	BS	CT	EA	HL	LR	NF	RA	RM	SA	SC	XG	XR	HI
Negombo	++	**	**	—	++	*	+	++	+++	—	+++	—	+++	**	+	+	+	—	4
Bentota	—	*	++	—	—	*	*	—	+	+	+	—	*	**	—	*	—	—	4
Balapitiya	+	+	+	—	—	+++	+++	++	*	+	+++	*	**	—	—	+++	—	—	4
Koggala	+	++	+	+	—	+	++	—	+++	—	+	++	*	***	—	*	—	+	3
Rekawa	*	++	*	+	—	*	++	*	**	+	*	+	+	+++	—	+	—	—	4
Ranna Oya	*	+	—	—	—	—	*	+	*	*	*	*	—	—	—	+	—	—	4
Kalametiya	+	—	*	—	—	—	—	—	*	—	*	—	—	—	—	***	—	—	4
Menik river	*	**	++	—	—	—	—	—	*	—	*	—	—	+++	—	**	—	—	0
Kumbukkan oya	+++	*	*	—	—	—	—	—	*	—	*	—	++	*	—	*	—	—	0
Batticaloa	+++	++	**	+	—	+++	—	—	**	+	*	—	++	*	—	+++	+	—	3
Valachcheni	++	+	***	—	—	+	—	—	*	+	++	—	—	**	—	—	+	—	4
Mahaweli	+++	—	+++	+	+	+++	—	—	++	—	*	—	+++	**	—	++	+	—	3
Mullaittivu	+	+	**	—	—	+	—	+	*	—	+++	—	—	**	—	++	—	—	3
Vadamarachchi	*	*	**	—	+	+	—	—	++	—	+++	—	—	**	—	*	—	—	4
Mannar	+++	*	**	—	—	+	—	+	+++	+	*	—	—	**	—	—	+	+	3
Kalpitiya	+	+	***	—	++	—	—	++	++	—	++	—	+	**	+	+	+	+	3
Kala Oya	+	++	**	—	+	+	—	++	++	—	++	—	+	**	+	—	+	+	1
Mi Oya	+	—	**	+	+	—	—	+	**	+	++	—	—	*	+	—	+	—	4
Mundel	—	+	***	—	—	+	—	—	**	—	+	—	—	—	—	—	—	—	5
Low-saline	+	*	+++	+	+	*	+++	++	+++	+	++	+	+++	*	+	++	+	+	
High-saline	+++	*	**	+	+	+	—	+	**	+	+++	—	+	**	+	++	+	+	

Table 5. Status of mangrove species and their distribution in different coastal areas of Sri Lanka. (1-very rare and endangered; 2- rare but not endangered; 3-common but restricted; 4-common; 5-very common). + indicates presence, — absence.

Mangrove species	Status	West	North-west	North	North-east	East	South-east	South	South-west
Acanthus ilicifolius	4	+	+	+	+	+	+	+	+
Aegiceras corniculatum	4	+	+	+	+	+	+	+	+
Avicennia marina	5	+	+	+	+	+	+	+	+
A. officinalis	3	+	+	—	+	+	—	+	+
Bruguiera cylindrica	3	+	+	+	+	—	—	—	—
B. gymnorrhiza	4	+	+	+	+	+	+	+	+
B. sexangula	3	+	—	—	—	—	—	+	+
Ceriops decandra	1	—	—	—	+	—	—	—	—
C. tagal	3	+	+	—	—	—	+	+	+
Cynometra iripa	2	—	+	—	+	—	—	—	—
Excoecaria agallocha	5	+	+	+	+	+	+	+	+
Heritiera littoralis	3	—	+	—	—	+	—	+	+
Lumnitzera littorea	1	—	—	—	—	—	—	—	+
L. racemosa	5	+	+	+	+	+	+	+	+
Nypa fruticans	3	+	—	—	—	—	—	+	+
Rhizophora apiculata	4	+	+	—	+	+	+	+	+
R. mucronata	5	+	+	+	+	+	+	+	+
Scyphiphora hydrophyllacea	2	—	—	+	—	—	—	—	—
Sonnaratia alba	3	+	+	—	—	—	—	—	—
S. apetala	1	—	—	—	+	—	—	—	—
S. caseolaris	4	+	—	+	+	+	+	+	+
Xylocarpus granatum	3	+	+	—	+	+	+	—	—
X. moluccensis	3	—	+	—	—	—	—	+	—
Total (23)		16	17	10	15	12	11	15	15

(e.g. bordering Mundel lake and at some places along the Puttalam-Kalpitiya road).

OVERWASH MANGROVE FORESTS. Overwash mangrove forests are those that are found on small islands, which get completely covered over at each high tide (e.g. in some of the small islands in Kalpitiya lagoon). Because of the tides washing away the leaf debris, etc., the organic content of the soil is low. Floristic composition of the overwash type could be similar to that of the high-saline type with *Rhizophora mucronata* dominating the mangrove community, but more often they are monotypic formations of *R. mucronata*.

BASIN MANGROVE FORESTS. In the basin type, the mangrove forest lies in a depression and the surrounding soil being washed into the basin. The soil is waterlogged, poorly aerated with a high organic content. The vegetation is similar to that of high-saline type with *Rhizophora mucronata* and *Avicennia marina* dominating the mangrove community. This type of mangrove forest is found in Vadamarachchi lagoon in the Jaffna peninsula (Balasubramaniam, 1985) but has not been observed on the west, south or east coasts.

Fauna

INVERTEBRATE FAUNA. A variety of macrofauna is observed in the mudflats within mangrove forests. The macrofauna in the Sri Lankan mangrove forests are dominated by gastropods and grapsid crabs. The snail *Terebralia palustris*, grapsid crabs and the mud-lobster, *Thallasina anomala*, appear to be specific to the mangrove forests. *Terebralia palustris* was observed in all mangrove forests, especially among the roots of *Rhizophora* spp. and other trees. It is abundant in Kalpitiya area but is not so common in the wet zone. On the other hand, *Cerithidea cingulata* is common in all mangrove forests and is also observed in mud flats with no associated mangrove forests. Grapsid crabs are common in all large mangrove forests and included *Chiromantes* spp., *Neosarmatium* spp. and *Neoepisesarma* spp. The fiddler crabs *Uca* spp. are found in mudflats within as well as outside the mangrove forests. The anomuran *Thallasina anomala* was seen in Mannar, Kalpitiya, Mi Oya, Kala Oya and Negombo and Batticaloa mangrove forests. Hermit crabs *Eupagurus* sp. and *Pagurus* sp. were seen in all mangrove forests.

Aquatic fauna in mangrove associated estuaries and lagoons is not different from that found in other estuaries and lagoons. Since the submerged parts of the trees and the prop- and knee-roots offer a substratum for attachment, and a place for hiding and protection, and the leaf litter offers protection and a source of food, aquatic fauna occurs in greater abundance in a mangrove-associated estuary or lagoon. The portunid crab *Scylla serrata*, which is commercially important in Sri Lanka, was found ubiquitously in all lagoons and estuaries examined, but is specially common in Kalpitiya lagoon. Several species of penaeid prawns were seen in lagoons and estuaries examined of which the common species were *Penaeus indicus*, *P. semisulcatus*, *Metapenaeus dobsoni*, and *M. elegans*. *Penaeus semisulcatus* is common in Kalpitiya area but is rare in the wet zone. *Macrobrachium* spp. (family Palaemonidae) are common in the estuaries of both dry and wet zones; *M. rosenbergii* is the commonest species, but *M. scabriculum* is also frequent. Atyid shrimps such as *Atyopsis spinipes*, *Caridina zeylanica*, *C. propinqua* and *C. gracilirostris* and the gastropod molluscs such as *Faunus ater* are found in the lagoons and estuaries of the wet zone.

The bivalves, *Anadara* spp., *Geloina ceylonica* and *Gaffrarium tumidum*, are common in the mud in the shallow lagoons and estuaries in the dry zone, and are found among sea grasses and occasionally within mangrove forests. The oysters, *Crassostrea* spp. are seen attached to the submerged roots of *Rhizophora* spp., etc. and in the shallow regions of all lagoons and estuaries. *Perna* spp., *Marcia* spp., *Pinna bicolor* and the gastropod *Pleuroploca trapezium* were found in the lagoons and estuaries of the dry zone. *Littorina scabra* and *Nerita polita* are found in both the wet and the dry zone mangrove forests.

Larvae of prawns and crabs, copepods and nauplii are common in the zooplankton of all lagoons and estuaries. However, some differences in the zooplankton in wet zone and dry zone lagoons and estuaries were observed. For instance, *Caprella*, spp. and *Noctiluca* spp. are common in large dry zone lagoons (e.g. those of Kalpitiya and Batticaloa) but not in wet zone lagoons. Zooplankton in Negombo lagoon is dominated by *Ceratium* spp. (Dinoflagellata); that of other wet zone lagoons is dominated by nauplii and

copepods. Cladocerans and rotifers are also observed in these lagoons but not in most of the dry zone lagoons.

VERTEBRATE FAUNA. Since the mangrove forests in Sri Lanka in general are quite small, the vertebrate fauna depends mainly on the composition of the fauna of the surrounding area. For instance, in mangrove forests surrounded by developed areas, the vertebrate fauna is quite sparse, except for the fish species the diversity of which depends on the size, freshwater inflow and salt water ingress of the respective lagoon or estuary.

The fish species found in lagoons and estuaries with associated mangrove forests are the common estuarine fish species which included mugilids, carangids, cichlids, siganids, centropomids, gobiids, etc. Over 150 species have been recorded in mangrove forest associated lagoons and estuaries (de Silva & de Silva, 1987). The fish fauna differs somewhat in the wet zone and dry zone estuaries and lagoons, although there are many common species, depending on the prevailing salinity. *Periophthalmus koelreuteri* is a prominent species on mudflats and seen resting on the prop roots of *Rhizophora* spp. in both the wet and the dry zones. Fish fry and fingerlings and small prawns are often seen in small more or less permanent water holes and small channels of water within the mangrove forests. Glass eels and juvenile eels were observed in water among the prop roots of *Rhizophora* spp.

Most of the tetrapod fauna can be considered as either "migrants" or "occasional visitors" from the surrounding area, although there are a few species, especially some bird species and megachiropteran species, which roost on mangrove trees.

Only a few amphibians were observed within mangrove forests. Common toad *Bufo melanostictus* and the common frog *Limnonectes limnocharis* were seen in many river estuaries. This paucity of amphibians is obviously due to the prevailing saline conditions.

The water snakes (*Xenochrophis piscator, Cerberus rhynchops* and *Gerada prevostiana*) as well as the land snakes (rat snake (*Ptyas mucosus*), python (*Python molurus*),green whip-snake (*Ahaetulla nasutus*), cobra (*Naja naja*) and Russell's viper (*Vipera russelli*)) were observed within mangrove forests. Baby crocodiles of both *Crocodilus palustris* and *C. porosus* were seen among the prop roots of *Rhizophora*, which provide good protection to them from predators such as the avian raptors.

A variety of birds is found to nest in mangrove trees and feed in the mangrove-associated lagoons and estuaries. Although some forest birds were observed, the mangrove forest avifauna comprises mainly wading birds. The resident avifauna is augmented by the migrant species during the migratory season of September to April. Over 110 species, both resident and migratory, have been recorded during this study in mangrove forest associated lagoons and estuaries, more in the dry zone than in the wet zone. However, none of these species is confined to the mangrove forests, but found as well in the estuaries and lagoons with no associated mangrove forests.

The mammalian fauna are mainly visitors. In developed areas, only a few species such as the rodents and bats were observed, but in areas where the mangrove forests continue with the Thorn or Evergreen forests, many mam-

mal species were found to visit the mangrove forests (e.g. mangrove forests in National Parks). In the mangrove forest of Pomparippu Ara-Kala Oya estuaries (in Wilpattu National Park) as well as in those of Menik river (including Katupila Ara and Agara Ara) and Kumbukkan Oya estuaries (in Ruhuna National Park) tracks and dung/scat piles of many mammal species including the elephant (*Elephas maximus*), water buffalo (*Bubalus bubalis*), sambar (*Cervus unicolor*), spotted deer (*Axis axis*), mouse deer (*Tragulus meminna*), wild pig (*Sus scrofa*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*) and jackal (*Canis aureus*) were seen. Troops of grey langur (*Presbytis entellus*) were also observed in mangrove forest areas. Otters (*Lutra lutra*) also visit the mangrove forests, perhaps to feed on crabs; their foot-prints were seen in the Kala Oya mangrove forest.

Impact of human activities on mangrove forests

Mangrove forests in Sri Lanka have been most abused by man. Human interference has affected the Sri Lankan mangrove forests in several ways.

a) Despite the low tidal amplitude, the mangrove forest cover in the past had been much more than what it is today. Tennent (1859), over 135 years ago, observed that the shores of Sri Lanka contained dense growth of mangrove forests. Human interference has reduced the extent of mangrove forests to the present very low level. In Negombo area, about 10% of mangrove forest cover has been cleared during the last decade despite conservation measures and a similar portion has been cleared between Chilaw and Kalpitiya for prawn farming.

b) Lack of tall trees, in general, in Sri Lankan mangrove forests is clearly due to selective removal of tall trees for various purposes. The presence of tall mangrove trees in some mangrove forests shows that mangrove trees can grow to a considerable height in Sri Lanka if left undisturbed.

c) Absence of a proper zonation of trees is also, at least partly, due to human interference. The established ecological balance, once disturbed, takes a considerable time to re-establish its proper order. This is especially true in a hostile environment such as the one in which mangrove forests develop. In some mangrove forests (e.g. that in the Rekawa estuary), the fringe formed by *Rhizophora* species has mostly disappeared. The root marks still visible in the zone indicate that at least some trees were removed very recently. In some areas of the Negombo mangrove forest, *Acanthus ilicifolius* extends right down to the water's edge and one small island is almost completely covered with this thorny shrub. *Acanthus ilicifolius* usually grows closer to the upper edge of the mangrove forest and its spread to other regions is indicative of selective removal of other species.

d) Development of many back mangrove species such as *Acrostichum aureum, Ardisia elliptica* and *Dolichandrone spathacea* among the true mangrove species even up to the edge of water in some mangrove forests is also a result of the selective removal of true mangrove species.

e) Absence or rarity of some true mangrove species in several mangrove forests is also probably due to selective removal of these trees. For instance,

Sonneratia spp. are very much less abundant than expected in many mangrove forests. *Nypa fruticans* is completely absent in several wet zone mangrove forests for no apparent ecological reason. According to eye witnesses, about 50-75 years back, *Nypa fruticans* grew well in estuaries such as those at Balapitiya, Hikkaduwa and Koggala and that of Gin river, Today very little is left of this species in these estuaries. In fact, according to the legend, the Gin river gets its name from the Sinhala name ("Gin Pol") of *N. fruticans*. The shallow areas in which *N. fruticans* grew have been cleared to construct pens for retting coconut husks for coir making. Such pens are a common sight in the estuaries in the south-west and may have contributed significantly to the destruction of mangrove forests in these localities.

Importance of mangrove forests

Mangrove forests grow in a very hostile environment in which wide fluctuations of temperature and salinity occur and anoxic conditions develop in the substratum. Most of the other trees and shrubs may not be able to survive in this environment. Mangroves entrap solar energy, which would otherwise not be available to the estuarine food web. They also entrap nutrient-rich sediment brought down by the rivers making new land and providing additional nutrients to the food web. Mangrove forests make the associated estuary highly productive, and also provide a variety of habitats and food sources for various animal species and excellent nursery grounds for young stages of shellfish and finfish. Abundance of food, availability of shelter and protection from predators, and suitable ecological conditions for growth, are very important to these fish larvae, fry and fingerlings.

These forests reduce shore and bank erosion, and act as a storm barrier as well. The effect of the hurricane that devastated Batticaloa and adjacent areas (Fig. 1) in 1979 would perhaps have been much less severe had there been a better developed mangrove forest on the shore.

Mangroves are also useful to Sri Lankans as a source of (a) firewood (mangrove wood burns well and has a low ash content), (b) poles and rafters for house-building, (mangrove wood contains tannins, which protect the wood from insects such as termites and wood-borers and make wood last longer), (c) tannins for staining fishing lines and nets, (d) animal fodder (e.g. *Lumnitzera* leaves), (e) attracting and trapping fish (fresh branches of mangrove trees placed in piles in the shallow estuary on decomposition will accumulate detritus and will be covered with a thick growth of algae and other aufwuchs, which in turn will harbour a variety of invertebrates; the fish, which will be attracted for food and shelter, can be encircled and captured with nets), and (f) food (tender leaves of *Acrostichum aureum* are made into a curry and eaten with rice; ripe fruits of *Sonneratia* spp. are crushed in water and made into a delicious drink).

Discussion

In Sri Lanka, although the mangrove formations have been traditionally referred to as "mangroves", the term "mangrove forest" has been used in this study because of the controversy in the use of the former term. In some coun-

Table 6. The length of coastline (km) occupied by different types of shore vegetation. (Source: Bandara, 1989.) (See also Fig. 1.)

Coast	Region	Total A	Mangrove B	Sandy seashore	Sand dune	Salt-marsh	Other	B/A
Western	Colombo-Puttalam	286	24	102	66	43	1	0.08
North-western	Puttalam-Elephant Pass	380	101	240	74	108		0.2
Northern	Elephant Pass-Chempiyanpattu	181	64	137	36	125		0.35
North-eastern	Chempiyanpattu -Foul Point	266	111	213	125	81		0.41
Eastern	Foulpoint-Potuvil	204	84	106	141	30	5	0.41
South-eastern	Potuvil-Hambantota	127	18	26	118			0.14
Southern	Hambantota-Galle	123	27	120	24	27	1	0.22
South-western	Galle-Colombo	135	42	131	4	4	1	0.31
Total		1,702	521*	1,075	588	418	8	
% Total			30.61	63.16	34.55	24.56	0.47	

* The estimate appears to be too high; the correct shoreline length is probably closer to half of this estimate (see text).

tries, the term "mangrove" is used to describe individual tree species (e.g. grey mangrove (*Avicennia marina*), red mangrove (*Rhizophora* spp.), river mangrove (*Aegiceras corniculatum*), milky mangrove (*Excoecaria agallocha*), large-leafed mangrove (*Bruguiera gymnorhiza*) (West, 1985)). To overcome this difficulty, Macnae (1968) advocated using the term "mangals" to describe the mangrove formations, reserving the term "mangroves" for individual species, but, this is not universally accepted (see Mepham and Mepham (1984), who discuss the semantics of various terms in some detail). The latter authors, after examining the suitability of various terms, recommended either the use of the term "mangroves" in its very broad definition or to call these formations "tidal forests". The latter term has been little used in Sri Lanka and other Asian countries, and therefore, the term "mangrove forest", which is more familiar to the Asians, has been used in this study, although some "mangrove forests" in Sri Lanka are not more than a few scattered trees.

Although the trees and shrubs found in the mangrove areas are usually categorised into "true" mangrove species (sometimes referred to as the "core" or "exclusive" mangrove species) and "mangrove associates" (or "back-mangrove" species) (Saenger, *et al.*, 1983), Mepham & Mepham (1984) have made serious objections to this division. They point out that, (a) there is no agreement between different authors on some of the arborescent species whether they are true mangroves or associates (there is for instance, no agreement between the authors even as to how many true mangrove species are there in the world (e.g. Walsh (1974) claims 55, Chapman (1976) 90 and Saenger *et al.*, (1983) 60)); (b) some of the true mangrove species grow quite well in purely freshwater environments away from the tidal influence (e.g. *Heritiera littoralis, Excoecaria agallocha, Lumnitzera racemosa* (and even *Avicennia* spp., *Bruguiera* spp., *Rhizophora* spp. and *Sonneratia* spp. which usually grow in association with estuarine waters) (Mepham & Mepham, 1984); in Sri Lanka, *Heritiera littoralis*

Table 7. Area (in ha) of mangroves in different administrative districts, A. in 1986 (according to Cosat Conservation Department, Anonymous, 1990) ; and B, in 1992 (according to Legg & Jewell, 1995) .

District	A	B
Ampara	100	292
Batticaloa	1,303	1,421
Colombo	39	39
Galle	238	187
Gampaha	313	122
Hambantota	576	539
Jaffna	2,276	260
Kalutara	12	70
Kilinochchi	770	312
Mannar	874	1,261
Matara	7	6
Mullaittivu	428	463
Puttalam	3,210	2,264
Trincomalee	2,043	1,491
Total	12,189	8,687

grows away from the tidal influence; *Bruguiera gymnorhiza* and *Aegiceras corniculatum* grow well in pure freshwater environments at least under experimental conditions (S. Balasubramaniam, pers. comm)); (c) some of the mangrove associates grow among true mangrove species (e.g. *Thespesia populnea, Terminalia catappa, Hibiscus tiliaceus* and *Barringtonia racemosa* (Mepham & Mepham, 1984); *Clerodendrum inerme, Hibiscus tiliaceus, Ardisia elliptica* and *Dolichandrone spathacea* grow among true mangrove species in some mangrove forests of Sri Lanka). Despite these objections, "true" mangrove species (which usually grow only on the intertidal shores of lagoons and estuaries) and "mangrove associates"(which usually grow on mangrove areas but on higher elevation away from the tidal influence) are recognised in the present study following other workers in southern and SE Asia (Saenger et al., 1983; Santisuk, 1985).

In Sri Lanka, the shoreline contains sea shore, sand dune, mangrove and salt marsh vegetation (Table 6). Mangrove forests in Sri Lanka are confined to

Table 8. Relationships between mangrove area, length of mangrove coastline and total coastline of some countries. (Data for countries other than Sri Lanka are from Saenger, 1983.)

Country	Mangrove area, A (km^2)	Mangrove coastline, B (km)	% total coastline	Ratio A/B
Sri Lanka	130	250*	14.7	0.52
Peninsular India	3,565	380	8.0	9.38
Peninsular Malaysia	11,368	381	20.0	2.98
Australia	11,617	6,064	22.0	1.92
Venezuela	6,736	1,102	33.4	6.11
Mexico	6,600	9,900	—	0.66

*see Table 6.

Table 9. The diversity of true mangrove species in Sri Lanka (present work), Peninsular India (Sing, 1985) Andamen & Nicobar islands (Dagar et al., 1991) and Thailand (Santisuk, 1985) in comparison to the number of species present in Asia and the world (Saenger, 1983). (The number of species in Tamil Nadu is also given as it is the nearest Indian state to Sri Lanka.)

Genus	World	Asia	Sri Lanka	India	(Tamil nadu)	Andaman & Nicobar Islands	Thailand
Acanthus	3	3	1	2	1	3	2
Aegialitis	2	1	0	1	0	1	1
Aegiceras sp.	1	1	1	1	0	1	1
Avicennia	11	5	2	3	2	2	3
Bruguiera	6	5	3	3	2	4	5
Camptostemon	2	2	0	0	0	0	0
Ceriops	2	2	2	2	2	2	2
Conocarpus	1	0	0	0	0	0	0
Cynometra	2	2	1	1	1	2	2
Excoecaria	1	1	1	1	1	1	1
Heritiera	2	2	1	2	0	1	2
Kandelia	1	1	0	1	0	1	1
Laguncularia	1	0	0	0	0	0	0
Lumnitzera	2	2	2	2	1	2	2
Nypa	1	1	1	1	0	1	1
Osbornia	1	1	0	0	0	0	0
Pelliciera	1	1	0	0	0	0	0
Phoenix	1	1	0	1	0	1	1
Rhizophora	8	8	2	2	2	4	2
Scyphiphora	1	1	1	1	0	1	1
Sonneratia	5	5	3	3	1	4	4
Xylocarpus	5	5	2	2	1	3	3
Total, A	60	44	23	29	14	34	34
% World		0.73	0.38	0.48	0.23	0.57	0.57
% Asia			0.52	0.66	0.32	0.77	0.77
Area of mangrove forests (km^2), B			130	3,565	150	1,150	1,634
A/Bx100			17.7	0.8	9.3	3.0	2.1

the muddy shores of estuaries and lagoons (Tansley & Fritsch, 1905) and not found on actual sea shores, which are sandy. On the other hand, extensive mangrove forests are found on the shores of the Straits of Malacca on the west coast of the Malay Peninsula. Although the length of shoreline containing mangrove formations has been estimated as 521 km (Bandara, 1989), it appears that the *Pandanus* formations in Sri Lanka are also included in this estimation. Although *Pandanus odoratissimus* grows in the back mangrove (Table 1), it is a maritime species of ocean beaches (Stone, 1981) and is usually found along the open shoreline with no associated mangrove forests. This estimate of mangrove shoreline is therefore too high. According to the observations of the present study, the actual figure appears to be closer to half of that given by Bandara (1989).

In Sri Lanka, the mangrove forests are more common (estimated as the mangrove shoreline per kilometre of total shoreline) in the northern, north-eastern and eastern coasts as well as the south-western coast, but least common in the western coast (Table 6). However, when area covered is considered, the administrative districts of Puttalam, Mannar (north-western region), Trincomalee (north-eastern) and Batticaloa (eastern) contain most mangroves (Table 7). When the ratio of mangrove shore line to total shoreline is considered, Sri Lanka has a relatively small mangrove shoreline in comparison to some other countries (Table 8). What is more, compared to several other countries, Sri Lanka has much smaller mangrove area per unit length of mangrove shoreline (Table 8).

Saenger *et al.*, (1983) list 60 'true' mangrove species in the world, 44 in the Asian region (Table 9). At least 23 of these occur in Sri Lanka in comparison to peninsular India's 29, Andaman and Nicobar Islands' 34 and Thailand's 34; the neighbouring Indian state of Tamil Nadu with its much longer shoreline is reported to contain only 14 species (Sing, 1985). This shows that Sri Lanka has a relatively high diversity of mangrove flora given its small area of mangrove forests; Sri Lanka contains 17.7 species per 100 km^2 of mangrove area in comparison to peninsular India's 0.8, Tamil Nadu's 9.3, Andaman and Nicobar Islands' 3.0 and Thailand's 2.1 (Table 9).

More mangrove species are present in north-western shore than elsewhere (Table 5). The number of species present in the dry zone (20) is slightly higher than that in the wet zone (18), but the number of species present in the high-saline mangrove forests (18) is less than that in the low-saline mangroves (22). However, when the five rare species are disregarded, the dry zone has 16 species, the wet zone 17, high-saline mangroves 16 and low-saline ones 18. The number of species varies from one location to another because of the patchy distribution of some of the species.

Some authors recognise two major kinds of mangrove forests in Sri Lanka which they refer to as the riverine and the fringing (or lagoon-fringing) mangrove forests (Balasubramaniam, 1985; Amarasinghe & Balasubramaniam, 1992). The riverine type is found in estuaries whereas the fringing type is found on the shores of lagoons and islands in lagoons. The floristic compositions of the riverine and the fringing forests are comparable, respectively, to those of the low-saline and the high-saline types described in the present work. The terms riverine and fringing, however, are rather inapt as some mangrove forests in the river mouths (especially in seasonal rivers of the dry zone) show characteristic fringing-type vegetation while others show characteristic riverine-type vegetation. The riverine type is also sometimes present on the shores of some lagoons. The different nature of flora and fauna of the two types is in fact due to different salinities prevailing in different systems. If the salinity in the adjacent lagoon is high, as in the large lagoons of Puttalam, Jaffna and Batticaloa, then the mangrove vegetation is characteristic of the fringing type. If on the other hand, the salinity of the adjacent lagoon remains low, as in wet zone lagoons, the mangrove forests will contain the characteristic vegetation of the riverine type. Some larger rivers flowing into large lagoons in the dry zone have a low-saline mangrove vegetation because of their high freshwater discharge (e.g. the annual discharge of Kala Oya and Mi Oya are,

respectively, 547 and 338 million cubic metres (mcm); that of Mahaweli river is 11,016 mcm (Somesekaram, 1988.)).

Mangrove development depends on the sheltered nature of the coastline. The coastline open to the sea, or a shore subjected to heavy winds or wave action, does not usually develop mangrove vegetation. It has either seashore vegetation or sand dune vegetation depending on the formation of the shore which in turn depends on the climate, ocean currents and tides. Some estuaries, especially those in the dry zone, are open to the sea only during a short period of the year during the major rainy season; during the rest of the year they remain cut off from the sea by sand bars (e.g. some estuaries in the south-eastern and eastern coasts). Thus, there is little direct tidal influence on them, although there is seepage of sea water through the sand bars. Even in the estuaries that remain open to the sea and in lagoons, the tidal influence is minimal since the tidal fluctuations are very low and seldom exceed 75 cm (Baldwin, 1991). Therefore, the land area subjected to tidal influence is very narrow, and this appears to be the primary reason why Sri Lankan mangrove forests are not extensive. However, because of the brackish nature of water, mangrove trees may grow upstream along the bank of a river for a considerable distance. For instance, along the banks of Katupila Ara and Agara Ara in the south-east, mangrove trees are present more than 1 km upstream of the river mouth, but this mangrove forest is only one to a few trees deep. Along the Bentota river in the southern coast, mangrove forests are present to a distance of about 5 km from the river mouth.

The pattern of rainfall and the resultant freshwater discharge (which also indirectly affect the degree of exploitation of the mangrove forests by influencing the relative ease with which the human settlements and crop plantations are established) also have marked effects on mangrove development as noted in the development of low-saline and high-saline mangrove forests.

Almost all mangrove forests in Sri Lanka (except where they are situated in protected areas) are disturbed by man to a greater or lesser degree. The effects of human interference on mangrove forests is clearly seen in some of the lagoons along the southern coast. In several larger lagoons with proper conditions for mangrove development, mangrove forests are absent. These lagoons are being used as salterns, such mangrove forests as did exist having been cleared (e.g. Bundala lagoon, Maha lewaya and Papatupana lagoon in the south-eastern coast). Salterns would have made these lagoons hypersaline, although their salinity would always have been high (e.g. Karagam Lewaya). Environs of some other lagoons are thickly populated and very little mangrove forests remain. In the lagoons of Ambalangoda, Hikkaduwa and Rathgama, most of the mangrove forests that were there had been reclaimed for establishing dwelling houses and homestead gardens, and coconut, rubber and cinnamon plantations. In others, the proper ecological zonation is often not seen. According to Watson's (1928) inundation classes described for Malaysian mangrove forests, which experience a tidal amplitude of several metres, the mangrove zonation would be: *Avicennia marina/Sonneratia alba/ Rhizophora* spp. at the edge of water followed by *Aegiceras corniculatum/ Avicennia officinalis/ Bruguiera* spp./*Ceriops tagal/Xylocarpus granatum* followed by *Acanthus ilicifolius/ Excoecaria agallocha/Lumnitzera racemosa/ Sonneratia caseolaris* in the inland

border. In Sri Lanka, such ecological zonation as did exist has clearly been disturbed by man in most places. This is well marked in the mangrove forests in the islands of Negombo lagoon. *Acanthus ilicifolius* is widespread and occurs in the *Rhizophora* zone in these forests. One small island is almost completely covered with *A. ilicifolius* while *Rhizophora* spp. were completely absent. Although some workers (Abeywickrama, 1964; Pinto, 1982) claim that the pioneering species is *Acanthus ilicifolius*, it is more likely that *A. ilicifolius* dominant vegetation is a result of selective destruction of other mangrove species by man allowing *A. ilicifolius* to spread (de Silva & Balasubramaniam, 1984). Macintosh (1982) is of the opinion that, in the Indo-Pacific region, the pioneering mangrove species in coastal deposition shores are *Avicennia* spp. and *Sonneratia* spp., and those in more estuarine localities are *Rhizophora* spp.

Although human interference has contributed greatly to the disappearance of significant areas of mangrove forests and led to the degradation of much of the mangrove habitats that do remain, contributing to the loss of zonation so that mangrove associates and even thorn scrub forest and evergreen forest plants grow intermingled with strictly mangrove plants, Sri Lankan mangrove forests remain narrow even where human interference is minimal. For instance, the mangrove forests at the estuary of Menik river, Katupila Ara and Agara Ara (the latter two waterways flow into Menik estuary) have not been subjected to human interference for a long time, as these are situated in a protected area (Ruhuna National Park (RNP) Block II). This area was a sanctuary from 1900 and became a part of RNP from 1954. However, in some places on the river bank, the mangrove 'forest' is only a border a few trees deep. The estuary is open to the sea only for a few weeks during the major rainy season, although there is some seepage of sea water through the sand bar, and therefore there is only a minimal tidal influence. The narrowness of the mangrove forest in this estuary suggests that the primary factor responsible for the narrowness of Sri Lankan mangrove forests is the small tidal amplitude. In open estuaries and lagoons such as the Kala Oya estuary and Kalpitiya lagoon where the tidal influence is more strongly felt, the mangrove forest area is much deeper.

Of the five rare mangrove species, *Ceriops decandra* was recorded in Mahaweli estuary in 1890 (Trimen, 1894) but has not been recorded since (Macnae & Fosberg, 1981a). *Sonneratia apetala* is found only in Koddyar Bay in Trincomalee (Fig. 1) in the NE dry zone, with only 5 or 6 tall trees remaining which may have been existing from before the 1880s (Trimen, 1894; Macnae & Fosberg, 1981b). There appears to have been no further colonisation. *Lumnitzera littorea* is found in the wet zone in two river estuaries. A few bushes are seen at present in both Bentota and Madu (Balapitiya) river estuaries. The plants in the Bentota estuary were known from 1894 (*Lumnitzera coccinea*, Trimen, 1900), but those in the Balapitiya estuary were recently (1983) discovered by the present authors. Both these mangrove areas are subjected to clearing for various developmental purposes. *Scyphiphora hydrophyllacea* is observed in Kalpitiya and Mannar mangrove forests in this study and has also been recorded from Jaffna (Trimen, 1894; Balasubramaniam, pers. comm.). *Cynometra iripa* was seen in Mi Oya estuary (present study) and has been recorded from Trincomalee (Mahaweli estuary) as well (S. Balasubramaniam, pers comm.). All five species, however, are widely distributed in the SE Asian region (Mepham &

Mepham, 1984). A single specimen of *Kandelia kandel* (=*Kandelia rheedei*) in Kew is said to be from Mahaweli estuary, but the occurrence of the species in Sri Lanka is doubtful (Trimen, 1894; Macnae & Fosberg, 1981a).

In early 1993, in Katupila Ara estuary in the south-east, *Sonneratia caseolaris* trees in one location died for no apparent reason. These trees, which previously grew to about 12-15 m, were located closer to the estuary opening. *Sonneratia caseolaris* trees further upstream were not affected but some in the intermediate location showed signs of distress but subsequently recovered. *Sonneratia caseolaris* trees in the adjacent Agara Ara were not affected. *Acanthus ilicifolius*, which also grew in the mangrove forest together with *S. caseolaris* was not affected and in fact showed more luxuriant growth after the death of the latter. There were a few bushes of *Lumnitzera racemosa* and these too were not affected. The dying occurred after the major flooding of the area owing to unusually heavy rains within a few days in December 1992. The area remained flooded for a few days until the sand bar blocking the mouth of the river was cut open. The probable explanation for the dying of these trees may be that due to inundation their pneumatophores were covered with freshwater and mud for a prolonged period of time which affected the root system. (This is somewhat comparable to the dieback observed in Horton Plains montane rain forest, although the latter is said to be mainly due to water deficit (Werner, 1988; Werner & Balasubramaniam, 1992).) Since other *S. caseolaris* trees in the adjacent areas were not affected this could not be due to a cyclical dieback.

Mangrove forests constitute one of the most abused ecosystems in Sri Lanka. The detrimental interference of man becomes more pronounced because of the relatively small extent of the mangrove cover in the island. Owing to indiscriminate and unscientific exploitation of this important resource, especially in the recent past, a large part of what had been mangrove forests only a few decades ago has now been converted into coconut, rubber and cinnamon plantations, homestead gardens and housing schemes, tourist facilities, and more recently, prawn culture ponds.

Until a few years ago, the mangrove forests were affected mainly by overexploitation by dwellers in the vicinity, mostly through their ignorance and poverty, and by the unplanned and unscientific reclamation and development for other purposes by the well-to-do. However, during the past few years the cutting down of mangrove forests for making prawn culture ponds has increased tremendously so that very little is left in most of the areas. This is especially clear in the west coast from Negombo to Kalpitiya, a stretch of about 300 km shoreline. The mangrove areas are considered the best for the intensive culture of the tiger prawn (*Penaeus monodon*), which fetches, at present, about Rs 500 per kg of 45-50 g individual weight class, and one ha pond would yield 5-6 metric tons (P.P.A. Fernando, pers. comm.). Since the growth period is about 4.5 months, two harvests can be obtained per year and the income from a one ha pond would be Rs 5–6 million, with a net annual profit of about Rs 3–4 million (US$ 50,000 – 70,000). Given such profitability, it is very difficult to curb conversion of mangrove forests into prawn farms. In fact the estimated area used for prawn farming at present is more than 800 ha (source: Central Environmental Authority, Colombo). Excessive discharge of nutrients and organic wastes leading to eutrophication and algal blooms, pollution due to

chemicals and pesticides used and the introduction of pathogens could severely affect the remaining mangrove forests and their associated fauna. Since mangrove soils are generally acid-sulphate soils, and since acid sulfates on exposure to air oxidise into sulphuric acid, the soil in these ponds rapidly becomes acidic leading to prawn-kills. This would probably make the owner shift his operation to a new location affecting more mangrove areas. In the near future, abandoned prawn-culture ponds are likely to constitute a serious problem in the area.

Since almost all mangrove forests of Sri Lanka have been subjected to degradation by man to a greater or lesser degree, and because this interference has increased dramatically in the recent years, conservation measures are urgently required. It may not be possible to eliminate altogether the exploitation of mangrove habitats, especially in the face of rapidly growing population in these areas and the high profit margins offered by prawn culture. It is best to attempt strict conservation of only the important and relatively undisturbed mangrove forests, e.g. that in Kala Oya estuary, and to introduce proper management measures for the optimum exploitation of the others without reducing the present area of mangrove cover or causing further degradation. A well planned replantation program in suitable areas will also greatly help to compensate for the damage caused by degradation.

Legislative measures alone will not be sufficiently effective without the co-operation of mangrove forest dwellers and other mangrove-users. This is demonstrated by the failure of the attempts of the Coast Conservation Division of the Ministry of Fisheries, the Central Environmental Authority, and the Forest Department (the watch dogs respectively for the management of coastal resources, properly planned developmental projects, and the conservation of forests), to curb the recent illegal large-scale cutting down of mangrove forests. The understanding by the mangrove forest users of the importance of the mangrove ecosystem and the role played by the latter in keeping the estuaries productive is essential for the success of conservation measures. Unless immediate steps are taken by the concerned authorities to properly manage and conserve what little is left, mangrove forests will soon disappear from Sri Lanka.

Sinnathamby Balasubramaniam.

Dedication

We dedicate this paper to the memory of the late Professor Sinnathamby Balasubramaniam (1936-1992) of the Department of Botany, Univeristy Peradeniya. Professor Balasubramaniam worked extensively on mangrove ecology and is perhaps best remembered for his outstanding contributions to phytosociology. His untimely demise on 3 April 1992 left a vacuum in Sri Lankan plant ecology research in general and mangrove research in particular, which will take a long time to fill.

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Literature cited

Abeywickrama, B.A. 1964. The estuarine vegetation of Ceylon. Proc. Dacca Symp., UNESCO. 207-210.

Aksornkoae, S. 1985. General background on mangrove ecosystem. *in* Proceedings of the Training Course on life history of selected flora and fauna in mangrove ecosystem. National Research Council of Thailand, Bangkok. 14 pp.

Amarasinghe, M.D. & S. Balasubramaniam. 1992. Structural properties of two types of mangrove stands on the north-western coast of Sri Lanka. Hydrobiologia, 247: 37-47.

Anonymous. 1990. Coastal Zone Management Plan. Sri Lanka Coast Conservation Department, Colombo. 81 pp.

Arulchelvam, K. 1968. Mangroves. Ceylon Forester, 8(3&4): 1-34.

Balasubramaniam, S. 1985. Tree flora in Sri Lanka, pp. 58-67 *in* Jayatilleke, A.. (Ed.), Proceedings of the International Conference on Timber Technology. (ed. Univ. of Moratuwa, Moratuwa, Sri Lanka.

Balasubramaniam, S., Rasiah, P. & M.L. Ratnapala, 1970. Mangrove vegetation in Vadamarachchi lagoon, Phyta, 1: 15-20.

Baldwin, M.F. (ed.). 1991. Natural Resources of Sri Lanka: Conditions and trends. Natural Resources, Energy and Science Authority of Sri Lanka, Colombo. 280 pp.

Bandara, C.M.M. 1989. A survey of the coastal zone of Sri Lanka. Coast Conservatioin Department of Sri Lanka. Colombo. 116 pp.

Chapman, V.J. 1976. (original not seen; as quoted by Mepham & Mepham, 1985).

Dagar, J.C., Mongia, A.D. & A.K. Bandyopadhyay. 1991. Mangroves of Andamen and Nicobar islands. Oxford & IBH Publishing Co., New Delhi. 166 pp.

de Silva, K.H.G.M. & S. Balasubramaniam. 1985. Some ecological aspects of the mangroves on the west coast of Sri Lanka. Ceylon J. Sci. (Bio. Sci.) 17&18: 22-42.

de Silva, K.H.G.M. & P.K. de Silva. 1987. An ecological study of the mangrove fauna in the west coast of Sri Lanka. Ceylon J. Sci. (Bio. Sci.), 19&20: 36-67.

Kanakaratne, M.D., Perera, W.R.T. & B.U.S. Fernando. 1984. An attempt at determining the mangrove coverage around Puttalam lagoon in Sri Lanka through remote sensing techniques. Proc. 4th Asian conf. Remote sensing. Colombo. 9 pp (mimeo).

Legg, C. & N. Jewell. 1995. A 1:50,000 - scale forest map of Sri Lanka: the basis for a national forest geographic information system. Sri Lankan Forester (special issue): 3-24.

Mackintosh, D.J. 1982. Fisheries and aquaculture significance of mangrove swamps, with special reference to Indo-West Pacific region, pp. 3-85 *in* Muir J.F. & R.J. Roberts (Eds.), Recent Advances in aquaculture. Croom Helm, London.

Macnae, W. 1968. A general account of the fauna and flora of mangrove swamps and forests in the Indo-West Pacific region. Adv. mar. Biol., 6: 73-270.

Macnae, W. & F.R. Fosberg. 1981a. Rhizophoraceae, pp. 487-500 *in* Dassanayake, M.D. & F.R. Fosberg (Eds.), Revised Handbook to the Flora of Ceylon. Vol. II. Smithsonian Institution, Washington, D.C.

Macnae, W. & F.R. Fosberg. 1981b. Sonneratiaceae, pp. 450-453 *in* Dassanayake, M.D. & F.R. Fosberg (Eds.), Revised Handbook to the Flora of Ceylon. Vol. III. Smithsonian Institution, Washington, D.C.

Mepham, R.H. & J.S. Mepham. 1985. The flora of tidal forests - a rationalization of the use of the term 'mangrove'. S. Afr. J. Bot., 51(2): 77-99.

Moldenke, H.N. & A.L. Moldenke. 1983. Avicenniaceae, pp. 125-136 *in* Dassanayake, M.D. & F.R. Fosberg (Eds.), Revised Handbook to the Flora of Ceylon. Vol. IV. Smithsonian Institution, Washington, D.C.

Perera, W.K.T. & P.P.G.S.N. Siriwardane. 1982. Topography of Puttalam lagoon. J. Inland Fish., 1: 97-104.

Pinto, M.L. 1982. Distribution and zonation of mangroves in the northern part of the Negombo lagoon (Sri Lanka). J. natn. Sci. Coun. Sri Lanka, 10(2): 245-255.

Pritchard, D.W. 1967. What is an estuary: physical viewpoint, pp. 3-5 *in* Lauff, G.H. (Ed.), Estuaries. Amer. Assoc. Adv. Sci. Publication No. 83, Washington, D.C. 3-5 pp.

Saenger, P., Hegerl, E.J. & J.D.S. Davie. 1983. Global status of mangrove ecosystems. The Environmentalist, 3 (Supplement 3): 1-88.

Santisuk, 1985. Explanatory notes to terrestrial trees and shrubs recorded from mangrove formation in Thailand. Proceedings of the Training Course on life history of selected flora and fauna in mangrove ecosystem. National Research Council of Thailand, Bangkok. 18 pp.

Sing, B.N. 1985. Mangroves of India. Proceedings of the Training Course on life history of selected flora and fauna in mangrove ecosystem. National Research Council of Thailand, Bangkok. 19 pp.

Somasekaram, T. (ed.).1988. National Atlas of Sri Lanka. Survey Department of Sri Lanka, Colombo. 141 pp.

Stone, B.C. 1981. Pandanaceae,. pp. 293-320 *in* Dassanayake, M.D. & F.R. Fosberg (Eds.), Revised Handbook to the Flora of Ceylon. Vol. III. Smithsonian Institution, Washington,

Tansley, A.G. & F.E. Fritsch. 1905. Sketches of vegetation at home and abroad. I. The flora of the Ceylon littoral. The New Phytologist, 4(1): 1-45.

Tennent, E. 1859. Ceylon, an account of the island. Vol. I. Longman & Roberts, London. 86 pp.

Trimen, H. 1894. A hand-book to the Flora of Ceylon. Part II. Bishen Singh Mahendra Pal Singh, Dehra Dun (Reprint, 1974). 392 pp.

Trimen, H. 1900. A hand-book to the Flora of Ceylon. Part V. Bishen Singh Mahendra Pal Singh, Dehra Dun (Reprint, 1974). 477 pp.

Walsh, G.E. 1974. Mangroves: a review, pp 51-174, *in*: Reimold, R.J. & W..H. Queen (Eds.), Ecology of halophytes (ed. . Academic Press, New York,. 51-174.

Watson, J.G. 1928. Mangrove forests of the Malay Peninsula. Malay For. Rec., 6: 1-275.

Werner, W.L. 1988. Canopy dieback in the upper montane rain forests of Sri Lanka. GeoJournal, 17.2: 245-248.

Werner, W.L. & Balasubramaniam S., 1992. Structure and dynamics of the upper montane rain forests of Sri Lanka, pp. 165-172 *in* Goldammer, J.G.. (Ed.), Tropical Forests in Transition. Birkhäuser Verlag, Basil. 165-172.

West, R.J. 1985. Mangroves. Agfact F2.0.1. Department of Agriculture, Sydney. 15 pp.

NOTE ADDED IN PROOF. Mangroves converted into prawn farms in the Puttalam-Kalpitiya area have already been abandoned following the outbreak of a virus ('white-spot disease'). This in turn has increased pressure on prawn farmers to look to clearing fresh areas of mangrove forests to establish new farms, posing a serious hazard to the wellbeing of these habitats.