

Mangrove ecosystems of the Indian Ocean region

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Covering about 47 % of world's mangrove area, containing 85 % of world's mangrove species, and occurring in a variety of habitats, the mangrove ecosystem plays a vital role in coastal biodiversity of 30 countries bordering the Indian Ocean. This ecosystem supports a rich species diversity of flora and fauna, but it is facing heavy human pressures and natural stresses, leading to a loss in biodiversity. This calls for urgent measures of conservation and management.

[Key words: Mangroves, Indian Ocean, East Africa, Arabian Peninsula, Indo-west Pacific, NW-Australia, associated flora, fauna, ecosystems]

Introduction

Mangrove forests are among the world's most productive ecosystems¹. They are the only forests situated at the confluence of land and sea in tropical and subtropical latitudes¹. With continuing degradation and destruction of mangroves, there is a critical need to understand the biodiversity of the mangrove ecosystems, more so in the countries bordering the Indian Ocean, since this is the place of origin for mangroves and where losses of the mangrove habitats are the greatest¹. Scattered information is available about the biodiversity of mangrove ecosystems from east Africa, Arabian Peninsula, Indo-west Pacific, and North-West Australia of the Indian Ocean region. This paper aims to review the available information and to assess the current status of biodiversity in mangrove ecosystems of the Indian Ocean region, in support of the international efforts of Census of Marine Life (CoML) with the theme of what is known, unknown and unknowable about marine populations and ecosystems.

Mangrove habitat

The total area of mangroves²⁻⁹ in the Indian Ocean region is 84,984.56 km² equivalent to about 47% of the total area of world mangroves (18 × 10⁶ hectares)³. About 30 countries (Fig. 1) of the Indian Ocean region (lat. 30°N-45°S; long. 32°E-130°E) have mangrove habitats with areas ranging from 1.08 km² in Comoros⁹ to 42,500 km² in Indonesia³. Indonesia alone accounts for 50% of the mangrove

area in the Indian Ocean region, followed by Myanmar (6,950 km²), Malaysia (6,410 km²), India (4,871 km²), NW Australia (4,513 km²), Bangladesh (4,500 km²), Madagascar (4,200 km²), Mozambique (4,000 km²), Pakistan (2,600 km²) and Thailand (1,900 km²) (Fig. 1). In few countries, especially in the arid regions of the Gulf, mangroves occur only in scattered patches.

In the Indian Ocean region, the mangroves are found in a variety of coastal settings, ranging from arid areas through estuaries, lagoons and deltas to coastal fringes. The functional types of mangroves in the Indian Ocean region are:

1. Over-wash mangrove forests – small mangrove islands, frequently over-washed by the tides.
2. Fringing mangrove forests – found along the waterways influenced by daily tides.
3. Basin mangrove forests – stunted mangroves, located in the interior of swamps.
4. Hammock mangrove forests – similar to basin type, but existing in more elevated sites.
5. Scrub mangrove forests – dwarf stands of mangroves, existing on flat coastal fringes.

The sheltered coasts support a luxuriant growth of mangroves and a higher biodiversity and this is because of the favourable conditions such as, muddy sediment, frequent water exchange, high rainfall and high humidity, prevailing in the areas. The best examples are mangroves of Sundarbans (India and Bangladesh), Malaysia and Indonesia. In contrast, the arid regions of Arabian Gulf countries, Pakistan and

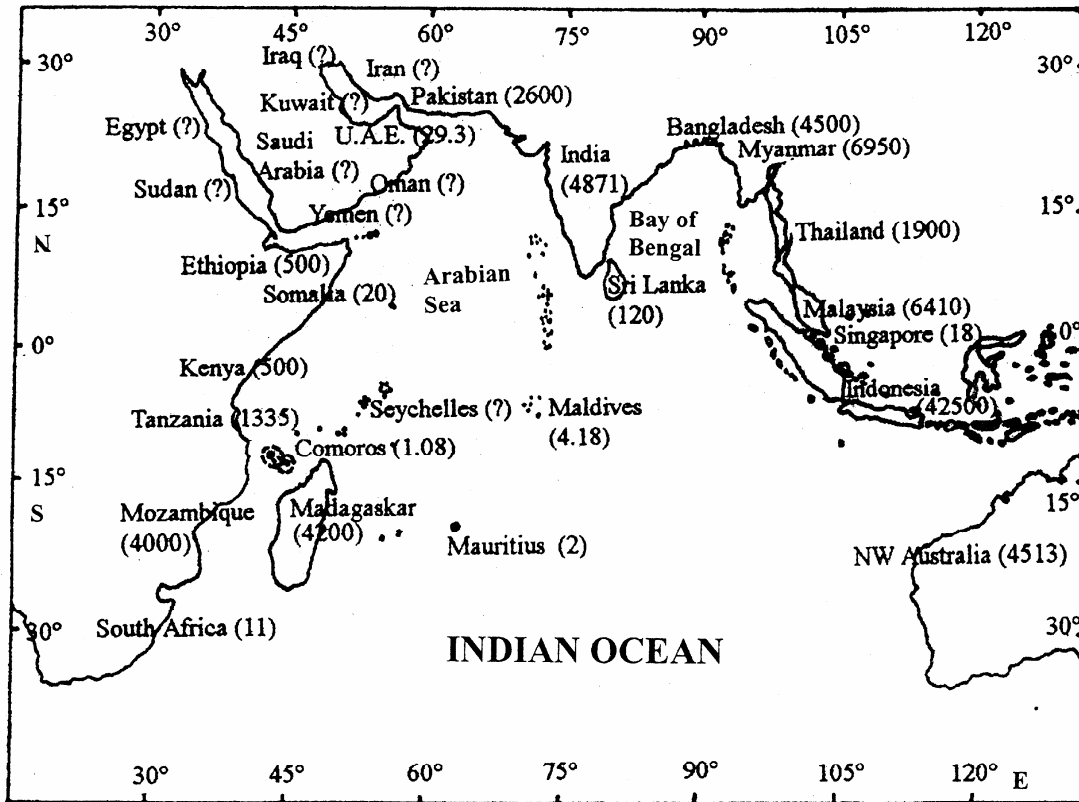


Fig. 1—Countries bordering the Indian ocean region indicating the area of mangroves in km² as given in parenthesis.

Gujarat (India), where the sediment is sandy, highly saline and poor in nutrients have only dwarf mangrove stands.

Diversity in mangroves

A total of 55 mangrove species (Table 1) belonging to 22 genera and 18 families are known from the Indian Ocean region. In other words, about 85 % of the total number of global mangrove species that is 65 species¹, are present in the region. Country-wise diversity ranges from 1 to 45 species (Table 1). Countries such as Indonesia (45 spp.), Malaysia (40 spp.), India (39 spp.), Thailand (34 spp.) and Singapore (31 spp.) are rich in mangrove species. Some species such as *Avicennia marina*, *Rhizophora mucronata*, *Acrostichum aureum*, *Bruguiera gymnorrhiza*, *Ceriops tagal* and *Xylocarpus granatum* are cosmopolitan in distribution and were recorded from many countries. Species such as *Sonneratia caseolaris*, *Excoecaria agallocha*, *Bruguiera sexangula*, *Aegiceras corniculatum* and *Nypa fruticans* are known from at least 10 countries (Table 1).

Fourteen species are endemic to the south-east Asia and northern Australia of the Indian Ocean region

(Table 1). This reflects their origin in the Indo-Malaysian region and subsequent dispersal to other parts of the world. Two species—*Rhizophora annamalayana* and *Heritiera kanikensis* are restricted to the east coast of India¹⁰. *Aegiceras floridum* and *Camptostemon philippensis* are found only in Indonesia. *Avicennia integra* and *Ceriops australis* are confined to Australia (Table 1). Other species with restricted distribution to only two countries—Malaysia and Indonesia, are *Aegiceras annulata*, *Avicennia lanata*, *Bruguiera exaristata*, *Camptostemon schultzei*, *Cynometra iripa*, *Sonneratia lanceolata*, *S. gulngai* and *S. urama*.

Besides endemism, discontinuous distribution is also of interest. *Sonneratia alba* has populations located on East Africa, India, Sri Lanka and Australia. *Sonneratia ovata* occurs only between Thailand and Indonesia. *Ceriops tagal* and *Bruguiera gymnorrhiza* show major discontinuities between eastern Africa and southwest Asia. *Aegialities rotundifolia* is restricted to shorelines of the Bay of Bengal and the Andaman Sea¹¹. Similarly, *Camptostemon schultzei* occurs in Indonesia and northern Australia¹².

Table 1—Occurrence and distribution of mangrove species in different countries bordering the Indian Ocean (+ Recorded; - Not Recorded)

No.	Name of the species	South Africa	Mozambique	Madagascar	Mauritius	Tanzania	Comoros	Seychelles	Kenya	Somalia	Ethiopia	Sudan	Egypt	Saudi Arabia	Yemen	Oman	U.A.E.
1	<i>Acanthus ebracteatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	<i>A. ilicifolius</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	<i>Acrostichum aureum</i>	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-
4	<i>A. speciosum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	<i>Aegiceras corniculatum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	<i>Ae. floridum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	<i>Aegialitis rotundifolia</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	<i>A. annulata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	<i>Aglaia cucullata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	<i>Avicennia alba</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	<i>A. marina</i>	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
12	<i>A. integra</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	<i>A. lanata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	<i>A. officinalis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	<i>Bruguiera cylindrica</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	<i>B. exaristata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	<i>B. gymnorrhiza</i>	+	+	+	+	+	-	+	+	-	-	-	-	-	-	-	-
18	<i>B. hainesii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	<i>B. parviflora</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	<i>B. sexangula</i>	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
21	<i>Ceriops decandra</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	<i>C. tagal</i>	+	+	+	-	+	-	+	+	+	-	-	-	-	-	-	-
23	<i>C. australis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	<i>Camptostemon schultzei</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	<i>C. philippensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	<i>Cynometra iripa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	<i>Dolichandrone spathaceae</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	<i>Excoecaria agallocha</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	<i>E. indica</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	<i>Heritiera fomes</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	<i>H. globosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	<i>H. littoralis</i>	-	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-
33	<i>H. kanikensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	<i>Kandelia candel</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35	<i>Lumnitzera racemosa</i>	+	+	+	-	+	-	+	+	-	-	-	-	-	-	-	-
36	<i>L. littorea</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	<i>Nypa fruticans</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	<i>Osbornia octodonata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	<i>Pemphis acidula</i>	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
40	<i>Rhizophora apiculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	<i>R. mucronata</i>	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
42	<i>R. stylosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
43	<i>R. x lamarckii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	<i>R. x annamalayana</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	<i>Scyphiphora hydrophyllaceae</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	<i>Sonneratia alba</i>	-	+	+	-	+	-	+	+	-	-	-	-	-	-	-	-
47	<i>S. apetala</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	<i>S. caseolaris</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49	<i>S. griffithii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	<i>S. ovata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
51	<i>S. lanceolata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	<i>S. x gulngai</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
53	<i>S. x urama</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54	<i>Xylocarpus granatum</i>	-	+	-	-	+	-	+	+	-	-	-	-	-	-	-	-
55	<i>X. mekongensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total number of species	6	9	9	3	9	3	8	9	3	1	1	1	2	1	1	1

Contd—

Table 1—Occurrence and distribution of mangrove species in different countries bordering the Indian Ocean
(+ Recorded; - Not Recorded)—Contd

No.	Name of the species	Kuwait	Iraq	Iran	Pakistan	India	Sri Lanka	Maldives	Bangladesh	Myanmar	Thailand	Malaysia	Singapore	Indonesia	NW Australia	Frequency of occurrence
1	<i>Acanthus ebracteatus</i>	-	-	-	-	+	-	-	-	-	+	+	+	+	-	5
2	<i>A. ilicifolius</i>	-	-	-	-	+	+	-	+	+	+	+	+	+	-	8
3	<i>Acrostichum aureum</i>	-	-	-	-	+	+	+	+	+	+	+	+	+	-	18
4	<i>A. speciosum</i>	-	-	-	-	+	-	-	-	-	+	+	+	+	+	6
5	<i>Aegiceras corniculatum</i>	-	-	-	+	+	+	-	+	+	+	+	+	+	+	10
6	<i>Ae. floridum</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	-	1
7	<i>Aegialiis rotundifolia</i>	-	-	-	-	+	-	-	+	+	-	-	-	-	-	4
8	<i>A. annulata</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	+	2
9	<i>Aglaia cucullata</i>	-	-	-	-	+	-	-	+	-	-	+	-	-	-	3
10	<i>Avicennia alba</i>	-	-	-	-	+	-	-	+	+	+	+	+	+	-	7
11	<i>A. marina</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	28
12	<i>A. integra</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
13	<i>A. lanata</i>	-	-	-	-	-	-	-	-	-	-	+	-	+	-	2
14	<i>A. officinalis</i>	-	-	-	-	+	+	-	+	+	+	+	+	+	-	8
15	<i>Bruguiera cylindrica</i>	-	-	-	-	+	+	+	-	+	+	+	+	+	-	8
16	<i>B. exaristata</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	+	2
17	<i>B. gymnorrhiza</i>	-	-	-	+	+	+	+	+	+	+	+	+	+	+	18
18	<i>B. hainesii</i>	-	-	-	-	-	-	-	-	-	+	+	-	+	-	3
19	<i>B. parviflora</i>	-	-	-	-	+	-	-	-	+	+	+	+	+	+	7
20	<i>B. sexangula</i>	-	-	-	-	+	+	-	+	+	+	+	+	+	+	10
21	<i>Ceriops decandra</i>	-	-	-	+	+	+	-	+	+	+	+	-	+	+	9
22	<i>C. tagal</i>	-	-	-	+	+	+	+	+	+	+	+	+	+	+	18
23	<i>C. australis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	+	1
24	<i>Camptostemon schultzei</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	+	2
25	<i>C. philippensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	-	1
26	<i>Cynometra iripa</i>	-	-	-	-	+	-	-	-	-	+	-	-	-	-	2
27	<i>Dolichandrone spathaceae</i>	-	-	-	-	+	+	-	-	-	-	+	+	+	-	5
28	<i>Excoecaria agallocha</i>	-	-	-	-	+	+	+	+	+	+	+	+	+	+	10
29	<i>E. indica</i>	-	-	-	-	-	-	-	+	+	-	+	+	+	-	5
30	<i>Heritiera fomes</i>	-	-	-	-	+	-	+	-	+	+	-	-	-	-	4
31	<i>H. globosa</i>	-	-	-	-	-	-	-	+	-	-	+	-	+	-	3
32	<i>H. littoralis</i>	-	-	-	-	+	+	-	-	-	+	+	+	+	-	9
33	<i>H. kanikensis</i>	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
34	<i>Kandelia candel</i>	-	-	-	-	+	-	-	+	+	+	+	+	+	-	7
35	<i>Lumnitzera racemosa</i>	-	-	-	-	+	+	+	+	+	+	+	+	+	+	16
36	<i>L. littorea</i>	-	-	-	-	+	-	-	-	+	+	+	+	+	+	7
37	<i>Nypa fruticans</i>	-	-	-	-	+	+	+	+	+	+	+	+	+	+	10
38	<i>Osbornia octodonata</i>	-	-	-	-	-	-	-	-	-	-	+	-	+	+	3
39	<i>Pemphis acidula</i>	-	-	-	-	+	+	+	-	-	+	+	+	+	+	9
40	<i>Rhizophora apiculata</i>	-	-	-	+	+	+	+	+	+	+	+	+	+	+	11
41	<i>R. mucronata</i>	-	-	-	+	+	+	+	+	+	+	+	+	+	+	19
42	<i>R. stylosa</i>	-	-	-	-	+	-	-	-	-	-	+	+	+	+	6
43	<i>R. x lamarckii</i>	-	-	-	-	+	-	-	-	-	-	+	-	+	+	4
44	<i>R. x annamalayana</i>	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
45	<i>Scyphiphora hydrophyllaceae</i>	-	-	-	-	+	+	-	-	-	+	+	+	+	+	7
46	<i>Sonneratia alba</i>	-	-	-	-	+	+	-	-	+	+	+	+	+	+	13
47	<i>S. apetala</i>	-	-	-	-	+	+	-	+	+	-	-	-	-	-	4
48	<i>S. caseolaris</i>	-	-	-	+	+	+	+	+	+	+	+	+	+	-	10
49	<i>S. griffithii</i>	-	-	-	-	+	-	-	-	+	+	+	-	-	-	4
50	<i>S. ovata</i>	-	-	-	-	-	-	-	-	-	+	+	+	+	-	4
51	<i>S. lanceolata</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	+	2
52	<i>S. x gulngai</i>	-	-	-	-	-	-	-	-	-	-	+	-	+	-	2
53	<i>S. x urama</i>	-	-	-	-	-	-	-	-	-	-	+	-	+	-	2
54	<i>Xylocarpus granatum</i>	-	-	-	-	+	+	-	+	+	+	+	+	+	+	13
55	<i>X. mekongensis</i>	-	-	-	-	+	-	-	+	+	+	-	+	+	+	7
	Total number of species	-	1	1	8	39	23	13	24	28	34	40	31	45	28	

Mangrove taxonomy needs much attention¹². For example, *Acrostichum* species are still poorly identified. *Sonneratia lanceolata* and *S. caseolaris* in Australia lack clear distinction in descriptions from Indonesia and Southeast Asia¹³. *Rhizophora apiculata* has under-leaf spots from Indo-Malaysia, but not in northern Australia¹⁴. *Rhizophora mucronata* from east Africa and Southeast Asia is not distinct from *R. stylosa*. *Acanthus ilicifolius* is not clearly identified from *A. ebracteatus*. For some species like *Avicennia marina* and *Ceriops tagal*, ecological varieties need to be recognized¹⁵. In addition, there are several natural hybrids, but their parental species are not clearly understood, especially for species of *Rhizophora*. Another problem in the taxonomy of mangroves is the confusion between the species of true mangroves and mangrove associates. Besides, often the same species is named differently at different sites, as in the case of *Avicennia rumphiana* and *A. lanata* and hence the total number of species is not constant¹⁶.

Lowest biodiversity areas

Arabian Peninsula

The mangrove species diversity is extremely low under arid climates as in the Arabian Peninsular region. The mangroves of the countries of this region—Saudi Arabia, Yemen, Oman, U.A.E., and Iran—are mostly mono-specific with *Avicennia marina*, but *Rhizophora stylosa* is also present sporadically in Saudi Arabia¹⁷. The Arabian Peninsula has high water salinity (>50 ‰) and high

sedimentation with pore-water salinity of 100 ‰. However, mangroves grow relatively well in the Persian Gulf (east of the Peninsula) but not in the Red Sea (west of the Peninsula). One reason is that the Red Sea has very low input of river water through very short perennial rivers, whereas the Arabian Gulf receives nutrient-rich waters from river discharge, especially from two rivers—Tigris and Euphrates¹⁷. In UAE, the bulk of *Avicennia marina* trees are present in few thousand acres from Kalba in the east, Rasal Khaimah in the North and Abu Dhabi and other islands in the west¹⁸.

African coasts

There are 11 species¹⁹ of mangroves in the east Africa coasts, along western Indian Ocean. Some of the best mangroves (trees >25 m tall) in east Africa are found on the Zambezi delta (Mozambique) and the Rufiji deltas (Tanzania)¹⁹.

Along east Africa, three species—*Avicennia marina*, *Rhizophora mucronata*, and *Ceriops tagal* are

predominant. The species rank next in abundance are *Lumnitzera racemosa*, *Xylocarpus granatum*, *Bruguiera gymnorrhiza*, *Sonneratia alba* and *Heritiera littoralis*. The rare species are *Bruguiera cylindrica*, *Avicennia officinalis*, *Ceriops boviniana* and *Xylocarpus moluccensis*. Interestingly, the mangrove biodiversity decreases towards the region of southeast Africa. South Africa has 11 km² of mangroves, represented with 6 species along the Kosi system near Mozambique. This number decreases to 3—*Avicennia marina*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata*—towards the south along the Richards Bay¹⁹.

In Mozambique, mangroves (4000 km²) are largely found along estuaries and large river mouths in Zambezi, Pungui, Buzi and Save flow⁷. A total of 9 species are known from Mozambique. The Zambezi delta has 8 species with large trees of *Rhizophora mucronata*, *Bruguiera gymnorrhiza* and *Heritiera littoralis*^{7,19}.

Madagascar⁸ has 9 species in 4200 km² area. Mauritius has only 2 km² area of mangroves with 3 species—*Acrostichum aureum*, *Bruguiera gymnorrhiza* and *Rhizophora mucronata*—occurring in very narrow strips⁵.

Tanzania⁶ has 9 species of mangroves in an area of 1335 km² found mostly along perennial and seasonal rivers. Some of the best mangroves are found in the Rafiji river delta. The mangroves grow there exhibit a distinct pattern of zonation. For example, *Avicennia marina* is associated with sandy sediment; *Rhizophora mucronata* with muddy sediment along rivers and creeks; *Ceriops tagal* with dry areas; *Bruguiera gymnorrhiza* with wet area; *Lumnitzera racemosa* and *Xylocarpus granatum* with landward fringe; *Sonneratia alba* on open coasts; and *Heritiera* and *Bruguiera* away from the open coast¹⁹.

Kenya⁴ has 9 species, existing in a total area of 500 km² with 50‰ of this lying in Lamu. In the Mida creek²⁰ of Kenya, 58‰ of the mangrove area is occupied by *Rhizophora mucronata* and *Ceriops tagal*.

Seychelles has 8 species of mangroves occurring largely in three areas—Aldabra, Cosmoled and Astove Islands^{19,21}. Comoros has 3 mangrove species in three areas—Moheli Island, Grande Comose, Anjouna⁹. Somalia also has less mangrove swamps, with only 3 species—*Acrostichum aureum*, *Avicennia marina* and *Ceriops tagal* occurring sporadically¹⁹. Mangrove stands in Egypt, Sudan and Ethiopia bordering the Red Sea, are mostly monospecific with *Avicennia*

marina, which are bushy in nature due to high salinity, low precipitation and low nutrients²². In Egypt, the mangroves are present in the floodwater valleys that enter the sea from the mountains. These valleys are mostly dry except during occasional rain storms, which supply freshwater and sustain the mangrove life²².

Pakistan coast

Mangroves in Pakistan occur mostly in the Indus delta, with an area of 2600 km² spreading along the coasts of Sindh and Balochistan Province³. There are 8 mangrove species in the Indus River delta region and 5 species along the Makran coast dominated with *Avicennia marina* (95%), followed by *Ceriops tagal* and *Aegiceras corniculatum*²³.

Maldives

Thirteen species of mangroves are found in 4.18 km² areas of coral islands—Kelai, Landhoo, Gaafaru, Kaashidu and Farukolhu. The number varies with areas, ranging from 2 in Gaafaru to 7 in Kelai and Landhoo²⁴. Among these, the dominant species are *Bruguiera cylindrica*, followed by *Lumnitzera racemosa*, *Ceriops tagal* and *Rhizophora mucronata*. The floral constituents are very much similar to Sri Lanka and other Gulf countries²⁴.

High biodiversity areas

Indian coastline

East coast of India has larger (about 80%) mangrove area than the west coast (20%) due to terrain and gradual slope as well as the river deltas of Ganges, Brahmaputra, Mahanadi, Godavari, Krishna and Cauvery. These deltas are nutrient-rich alluvial soil where mangroves grow luxuriant with 60 species²⁵. Sundarbans forest along the east coast is one of largest mangrove forests in India. Along the west coast, there are 34 species of mangroves found on banks of estuaries, deltas, backwaters, creeks and other protected areas²⁵. Lakshadweep Islands group has only a small patch of *Bruguiera parviflora* on Minicoy Island²⁶.

Twenty species¹⁰ of mangroves are now becoming endangered because of several reasons such as, grazing by cattle/goat/camel; tree felling for timber and firewood; human inhabitation and pollution; embankment; hypersalinity; siltation; aquaculture and agriculture practices; natural calamities like cyclone; and disease problems¹⁰. Government of India has identified 35 mangrove areas for intensive

conservation and management. A National Mangrove Genetic Resource Centre has been established in Orissa which has the maximum species diversity of mangroves. Research activities are encouraged on the following aspects — (i) taxonomy and distribution of mangrove species, (ii) status of endangered species and measures for their conservation, (iii) restoration of degraded mangrove areas, (iv) status of health of mangroves, (v) biodiversity of mangroves including flora, fauna and microorganisms and their interrelationships, (vi) studies on aquaculture in the mangrove areas, and (vii) impact of mangrove afforestation on the coastal erosion and role of mangroves in flood damage control.

Sri Lanka

Sri Lanka has a total area³ of 120 km² of mangroves, present around the coastal lagoons, with 23 species²⁷. The mangroves are extensive in northwestern and northeastern coastlines. The largest patch is in Puttalam-Kalpitiya lagoon. The second largest patch is at Batticaloa followed by Jaffna Peninsula. *Nypa fruticans* is restricted to west coast. *Xylocarpus* species are widely present in east and west coasts²⁷.

Bangladesh

Sundarbans, in India and Bangladesh, is the largest continuous mangrove forest in the world and is the only mangrove forest infested with tigers. Of this, 62 % lies in Bangladesh at the southern end of the Ganges River²⁸. This comprises 44 % of the productive forest of Bangladesh contributing about one-half of forest-related revenue. Salinity plays an important role in the growth, species distribution and productivity of the forest and vegetation tends to be more luxuriant at lower salinity levels. There are 24 species of mangroves, among which *Heritiera fomes* and *Excoecaria agallocha* are dominant, with *H. fomes* alone contributing to 63.8% of the total forest produce²⁸.

Myanmar (Burma)

Myanmar has 28 species²⁹ in an area of 6,950 km², with the major mangrove forests lying in the Irrawaddy river delta. Not much is known about mangrove ecology and biodiversity but *H. fomes* is likely to become endangered soon²⁹.

Thailand

There are 34 species³⁰ of mangroves, present in an area of 1900 km², 80% of which is present in the west

coast of the Peninsula and the Andaman Sea coast. Dominant genera are *Rhizophora*, *Avicennia*, *Sonneratia*, *Bruguiera*, *Xylocarpus*, *Lumnitzera*, *Ceriops* and *Excoecaria*³¹. *Rhizophora* and *Avicennia* dominate in riverbanks followed by *Bruguiera*, *Ceriops*, *Xylocarpus* and *Excoecaria* in inland areas with drier soils and less tidal inundation. This country is rich in *Sonneratia griffithi*, which is rare in other mangrove areas. The luxuriant mangroves may be mainly attributed to high rainfall (4014.8 mm), clay loam, and/ or sandy clay sediment³⁰.

Malaysia

The area of mangroves in this country is 6410 km², — 17% in Penninsular Malaysia, 26% in Sarawak and 57% in Sabah³¹. The mangroves along west coast occupy 96% of the total area. The total number of mangrove species is 40. *Nypa fruticans* is abundantly present, but is an endangered species in most of other areas of mangroves in the world³². A well-managed mangrove forest is found in Matang Reserve³¹.

Singapore

Singapore has 31 mangrove species³³, scattered in an area of 18 km² along the coast, and especially in the silt deposited coasts of Northern and Western parts facing the Johore Straits, Pulau Ubian, and Pulau Tekong³³.

Indonesia

Mangroves are distributed in 42,500 km² in 17,000 islands of Indonesia³⁴. This high diversity and luxuriant growth of mangroves could mainly be attributed to high rainfall of 4000 mm and high humidity³². There are 45 species of mangroves, highest diversity in the Indian Ocean region. *Aegiceras floridum*, a rare species is present in lime stone rocky coast. Other two species that are found only in Indonesia and Australia are *Camptostemon schultzei* and *Bruguiera exaristata*³⁴.

North Western Australia

There are 28 mangrove species^{12,35}, occurring in an area of 4513 km². The endemic species are *Avicennia integra* and *Ceriops australis*¹². Species diversity is more in Northern Australia than in other coastal areas, and is often higher in estuaries and/ or in areas of higher rainfall³⁶.

Mangrove associated flora

The mangrove ecosystems are in general rich in associated flora that includes bacteria, fungi, algae,

seagrasses, lichens, salt-marsh and other vegetation. The diversity of associated flora is high in humid and wet regions, and it is poor in arid regions. The mangrove-associated flora reported in different countries of the Indian Ocean region is given in Table 2. Much more studies are required on the mangrove-associated flora, especially the microorganisms in the mangrove ecosystems of the region.

In India, the mangrove ecosystems have 809 species of associated flora³⁷ that includes 12 species of salt-marsh vegetation, 11 species of seagrasses, 559 species of algae, 69 species of bacteria, 103 species of fungi, 23 species of actinomycetes, and 32 species of lichens (Table 3). In Bangladesh, 330 species of plants have been recorded²⁸. In Indonesia, 189 species of plants that include 80 species of trees, 24 lichens, 41 ground-covering plants, 41 epiphytes and 3 plant parasites have been recorded³⁸. In Malaysia, 57 mangrove associate species are present, besides 9 species of bryophytes and pteridophytes³⁹.

In Thailand⁴⁰, 18 species of epiphytes that include 13 species of orchidaceae (species of *Dendrobium*, *Bulbophyllum*, and *Eria*) and an abundant epiphyte species — *Hoya parasitica* (Asclepiadaceae) are present. Many periphytic algae (*Catenella*, *Bostrychia*, *Murrayella*, *Gracilaria*, *Hypnea*, *Gelidium*, *Acanthophora*, *Herposiphonia*, *Laurencia*) and mud-dwelling algae (*Cladophora*, *Chaetomorpha*, *Enteromorpha*, *Ulva*, *Lyngbya*, *Oscillatoria*, *Phormidium*, *Calothrix*, *Hydroclathrus*, *Ectocarpus*, and *Dictyota*) are found in the mangrove forests⁴⁰.

East Africa coast has 8 salt-marsh and other halophytes, 2 lichens, 1 seagrass species and about 17 algal species^{19,41}. A survey of the coastal zone of Abu

Table 2—Number of mangrove-associated flora reportedly occurring in countries bordering the Indian Ocean

Country	No. of species	Group recorded
India ³⁷	809	Algae, bacteria, fungi, actinomycetes, lichens, seagrasses, saltmarsh and other halophytes
Bangladesh ²⁸	330	-do-
Indonesia ³⁸	189	Tree species, lichens, ground-covering species, epiphytes and plant parasites
Malaysia ³⁹	66	Including bryophytes and pteridophytes
Thailand ⁴⁰	18	Including orchids, epiphytes, algae
East Africa ^{19,41}	28	Algae, seagrasses, lichens, saltmarsh and halophytes
U.A.E. ⁴²	22	Halophytes

Dhabi (U.A.E.) identified 22 halophytes, of which 9 are tolerant to inundation of seawater⁴².

Mangrove-inhabiting fauna

Fauna in mangrove ecosystems is large and diverse as it includes both terrestrial and aquatic organisms. It is composed of large varieties of zooplankton, benthos, shrimps, crabs, molluscs, insects, finfish, birds, reptiles, amphibians and mammals. The muddy or sandy sediments of the mangroves provide habitats for epibenthic, infaunal and meiofaunal invertebrates. Water channels, which exist within the mangrove ecosystems support communities of zooplankton and fishes.

A total of 1511 species of fauna have been recorded in the Indo-Malaysian region³ and 754 species in the Australasian region³ of Indian Ocean, whereas there is no information for East African and Gulf countries (Table 4). In the Indo-Malaysian region, insects are dominant (500 species), followed by fishes (283 species), crustaceans (229 species) and molluscs (211 species). Among other groups, echinoderms are represented by a single species, amphibians by 2 species, coelenterates and ctenophores by 3 species and sponges and bryozoans by 5 species³ (Table 4).

The total number of mangrove-inhabiting faunal species³⁷ in Indian mangroves is 3,111 (Table 3). This

includes 55 species of prawns (1.8 % of total fauna), 138 species of crabs (4.4 %), 308 species of molluscs (9.9 %), 745 species of other invertebrates (23.9 %), 546 species of fish (17.6 %), 7 species of fish parasites (0.2%), 711 species of insects (22.9 %), 85 species of reptiles (2.7 %), 13 species of amphibians (0.4 %), and 70 species of mammals (2.3 %)³⁷. The faunal species are found to be present in large numbers in the Sundarbans of West Bengal followed by the Andaman and Nicobar Islands³⁷.

The faunal species which are frequently recorded in mangrove habitats are shrimps (*Penaeus indicus*, *P. monodon*, *P. semisulcatus*, *P. japonicus*, *Metapenaeus monoceras*), crabs (*Scylla serrata*, *Sesarma* and *Uca* species), molluscs (*Terebralia* spp., *Cerithidea*, *Nerita* and *Crassostrea* spp.) and finfish (*Periophthalmus* spp.). Information on other invertebrates are generally meager more so from mangroves of East African region.

Status of mangroves

The mangrove ecosystems continue to disappear especially in the Indian Ocean region. The universal causes of the destruction are shrimp culture, wood chip and pulp industry, urban development and human settlements and domestic uses for timber, firewood and fodder.

In dry areas, grazing by buffaloes, sheep, goats, camel can also lead to destruction of mangroves. In

Table 3—Total number of floral and faunal species in mangrove ecosystems of India³⁷

No	Group of organisms	No. of species	
		Sub-group total	Total
I	Mangroves (principal species)	39	39
II	Mangrove-associated Flora:		809
1	Bacteria	69	
2	Fungi	103	
3	Algae	559	
4	Lichens	32	
5	Actinomycetes	23	
6	Seagrasses	11	
7	Saltmarsh vegetation & other halophytes	12	
III	Mangrove-inhabiting Fauna:		3,111
1	Crabs	138	
2	Prawns	55	
3	Molluscs	308	
4	Other invertebrates	745	
5	Insects	711	
6	Fish	546	
7	Fish Parasites	7	
8	Birds	433	
9	Amphibians	13	
10	Reptiles	85	
11	Mammals	70	
	Total number of species		3,959

Table 4—Number of faunal species in mangrove ecosystems of different regions of the Indian Ocean region

No.	Animal taxa	East Africa & Gulf countries ³	Indo-Malaysia ³	Australasia ³
1	Protozoa	-	18	-
2	Sponges – Bryozoa	-	5	7
3	Coelenterata - Ctenophora	-	3	6
4	Non-polychaete worms	-	13	74
5	Polychaetes	-	11	35
6	Crustaceans	-	229	128
7	Insects – Arachnids	-	500	72
8	Molluscs	-	211	145
9	Echinodermata	-	1	10
10	Ascidians	-	-	8
11	Fish	-	283	15
12	Reptiles	-	22	3
13	Amphibians	-	2	0
14	Birds	-	177	244
15	Mammals	-	36	7
	Total number of faunal species		1511	754
	– No record			

areas such as Gulf countries, oil pollution is often harmful for survival of mangroves. A natural cause that results in large-scale destruction of mangroves is cyclones in Bay of Bengal that gets aggravated with human interference⁴³. Diversion of river water leading to hypersalinity in the downstream areas is a serious problem in the Indus delta of Pakistan, Cauvery and Sundarban deltas of India. Due to reduction in freshwater inputs, the freshwater-loving species like *Nypa fruticans* and *Heritiera fomes* become reduced in population density.

Fish and prawn seed resources of mangroves are largely destroyed. To cite an example, in Sundarbans, about 40,000 people harvest about 540 million seeds of tiger prawn (*Penaeus monodon*) every year, and in this process, about 10.6 billion seeds of other fishes and shrimps are killed, which will have impact on fish diversity and fisheries resources⁴⁴.

Field studies are required (i) for resolving the disputes in taxonomy of species, (ii) for assessment of the species under threat and (iii) for evolving the remedial measures for the specific causative factors responsible for the loss of biodiversity and degradation of mangrove habitats. For example, the problem of die back disease of *Heritiera fomes* causing a severe loss of mangroves in Bangladesh²⁸ deserves serious attention.

Trials of mangrove restoration are taking place in many countries, but planting strategies need improvement. Very often, massive plantations are made with few species, which would further pose a threat to diversity. Much more support is necessary for mangrove rehabilitation and biodiversity enrichment, and for continuous assessment of the impact of mangrove planting. A major challenge in conservation of biodiversity is to evolve the best management and restoration of mangrove forests integrated with improved coastal zone planning and sustainable technologies.

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