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Mangroves of South India and Sri Lanka, and Maldives CR

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Abstract
Mangroves of South India and Sri Lanka, and Maldives is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology). It includes the marine ecoregions of Western India, South India and Sri Lanka, and Maldives. The mapped extent in 2020 was 249.2 km^2, representing 0.2% of the global mangrove area. The environmental settings of this ecoregion differ widely ranging from open coast, lagoonal, deltaic and estuarine mangrove formations. The mangroves of Maldives grow on a calcareous mud substratum; those in all other parts of this ecoregion occur on fine terrigenous sediments. The biota is characterized by 21 species of true mangroves.

The mangroves of the southernmost east coast of India are dominated by a single, highly saline-tolerant species: *Avicennia marina*. In contrast, elsewhere in this ecoregion, diverse species constitute the mangrove floral community. There are at least five endangered mangrove-associated bird species and one shark species in the IUCN Red List. The major threats to the mangroves of this ecoregion are reduction in freshwater flow and subsequent development of hypersaline conditions; conversion of mangroves for aquafarming and tourism development; changes in sediment dynamics; poor exchange of tidal water; and climate change especially sea-level rise and storm surges.

Today the South India, Sri Lanka, and Maldives mangroves cover ranges between 197.1 and 249.2 km^2 according to different available sources. This is higher than our broad estimation for 1970. The mangrove net area change fluctuates between -4.7 and -26.8% 1996 to 2020 based on the data sources. If this trend continues, an overall loss between 49% and 58 % is projected over the next 50 years. Under a high sea-level rise scenario (IPCC RCP8.5) 82.7% of this ecoregion's mangroves would be submerged by 2060. Moreover, 3.2% of the mangroves are undergoing degradation, with the potential to increase to 9.5% within a 50-year period, based on a vegetation index decay analysis. Overall, the South India and Sri Lanka, and Maldives mangrove ecosystem is assessed as **Critically Endangered (CR).**

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Keywords:
Mangroves; Red List of ecosystems; ecosystem collapse; threats.

Ecosystem classification:
MFT1.2 Intertidal forests and shrublands
Assessment's distribution:
South India, Sri Lanka, and Maldives province
Summary of the assessment

Criterion	A	B	C	D	E	Overall
Subcriterion 1	LC	LC	DD	DD	NE	
Subcriterion 2	VU	LC	CR	LC	NE	CR
Subcriterion 3	DD	LC	DD	DD	NE	

CR: Critically Endangered, VU: Vulnerable,
LC: Least Concern, DD Data Deficient, NE: Not Evaluated

Mangroves of South India and Sri Lanka, and Maldives

CR

1. Ecosystem Classification

IUCN Global Ecosystem Typology (version 2.1, Keith *et al.* 2022):

Transitional Marine-Freshwater-Terrestrial realm

MFT1 Brackish tidal biome

MFT1.2 Intertidal forests and shrublands

MFT1.2_4_MP_21b Mangroves of the South India, Sri Lanka, and Maldives

IUCN Habitats Classification Scheme (version 3.1, IUCN 2012):

1 Forest

1.7 Forest – Subtropical/tropical mangrove vegetation above high tide level**below water level*[1]

12 Marine Intertidal

12.7 Mangrove Submerged Roots

Monospecies stand of Avicennia marina in Karangadu mangroves, Southeast coast of India (Photo credit: Selvam Vaithilingam)

[1] Note on the original classification scheme. This habitat should include mangrove vegetation below water level. Mangroves have spread into warm temperate regions to a limited extent and may occasionally occur in supratidal areas. However, the vast majority of the world's mangroves are found in tropical/subtropical intertidal areas.

2. Ecosystem Description

Spatial distribution

The Mangroves of South India and Sri Lanka, and Maldives include intertidal forests and shrub lands of the marine ecoregions of South India and Sri Lanka, and Maldives. These ecoregions include the coastal areas of Southeastern India (lower half of the Cauvery Delta and south) and Southwestern India (the southern part of the state of Kerala) and the entire coastlines of Sri Lanka and the Maldives (Figure 1). The estimated extent of mangroves in these ecoregions was 249.2 km^2 in 2020, representing about 0.2% of the global mangrove area. There represents a loss of 26.8 % since 1996 (Bunting *et al.,* 2022).

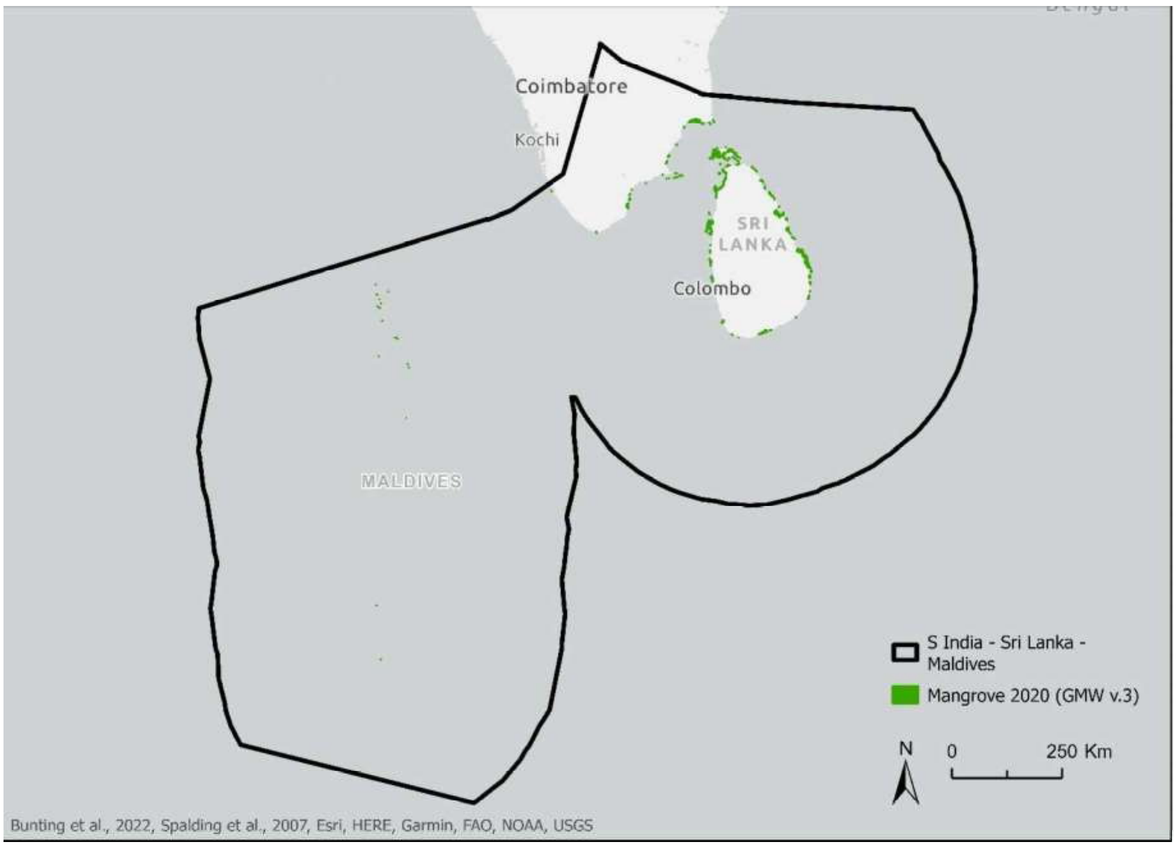


Figure 1. The mangroves of South India and Sri Lanka, and Maldives.

The mangroves of southeastern India are deltaic in nature, and the climate is semi-arid, whereas the mangroves of southwestern India are located around backwaters with wet climatic conditions. The coastal areas of Sri Lanka are divided into wet and dry zones and an intermediate zone based on average annual rainfall. The wet zone in the southwest part of Sri Lanka receives, on average, about 2,500 mm of rainfall, occurring almost throughout the year. The north, east, northeast and southwest coastal areas are comparatively dry with an average rainfall of 1,500 mm, mostly during the northeast monsoon season (October to January) and they remain dry for about five months from May to September. Mangroves are distributed in all coastal districts of Sri Lanka. North Western Province has the highest mangrove species diversity, while the largest mangrove cover is in the Northern Province. Extensive mangroves occur in the dry zone around large lagoons such as Puttalam, Mannar, Jaffna, Trincomalee and Batticaloa.

The mangroves of Maldives are found both in the northern and southern atolls, but the most luxuriant and diverse mangroves are in the northern atolls. In Maldives, the mangrove ecosystem is present in five different microenvironmental settings: i) the fringe area of some of the islands, where wave energy and wind speed are less and brackish water is present due to the mixing of seawater with the margin of the freshwater lens; ii) in between two islands, where the water is shallow, and there are accumulated deposits of sediments; iii) along the borders of lagoons that are connected to the sea; iv) along the borders of lagoons that have lost connection to the sea, but still receive seawater periodically through seepage; and v) in shallow depressions deep inside the islands, where rainwater accumulates (Selvam, 2003). These environmental settings significantly influence both the abiotic processes and biotic components of the mangrove ecosystem.

Biotic components of the ecosystem (characteristic native biota)

The mangroves of the South India and Sri Lanka, and Maldives ecoregions are biologically diverse with 21 recorded true mangrove plant species (IUCN, 2022). Recently, however, Veettil *et al*., (2023) reported 32 mangrove species in Sri Lanka, including *Rhizophora annamalayanaa* a natural hybrid in the Family Rhizophoraceae; and three locally critically endangered species namely *Lumnitzera littorea, Ceriops decandra* and *Xylocarpus rumphii*. However, *Xylocarpus rumphii* is usually associated with more rocky and sandy habitats above high water mark, rather than intertidal mangrove forests. In Maldives, Dryden *et al*. (2020) reported *Bruguiera hainesii* a rare species classified as critically endangered (CR) in the IUCN Red List.

The community structure of the mangroves varies in different environmental settings within these ecoregions shows some interesting features, reflecting prevailing conditions. The floral community structure of Muthupet mangroves and all other small patches located south of, it shows complete dominance of a single species, *Avicennia marina (*Azariah *et al.*, 1992). This is mainly because of hypersaline conditions that prevail on the southernmost east coast of India. In contrast, mangroves on the southernmost west coast of India are dominated with species tolerant of low salinity such as *Acanthus ilicifolius*, *Avicennia officinalis, Excoecaria agallocha, Bruguiera cylindrica* and *B. gymnorhiza*.

The Sri Lankan mangroves are highly diverse in their species composition and distribution. Their floristic composition shows closer affinity to the Madagascar mangrove wetlands (Amarasinghe and Perera, 2017) than to the mangroves of India. The mangrove floral diversity is high in Sri Lanka's northwest province followed by western and southern provinces. Their maximum extent is seen in Jaffna District in the northern province, while the lowest species diversity is found in Matara District in the Southern Province. *Rhizophora annamalayana* is the only natural mangrove hybrid, occurring in Sri Lanka (Veettil *et al*., 2023)

Jayathissa (2012) reported 21 true mangroves species and 24 species of mangrove associates in Sri Lanka, while Gunawardena *et al*. (2016) recorded 23 true mangrove species. There are no reports of endemic species in Sri Lanka. *Aegiceras corniculatum*, *Avicennia marina*, *Avicennia officinalis*, *Bruguiera gymmnorhiza*, *Excoecaria agallocha*, *Heritiera littoralis*, *Lumnitzera racemose*, *Rhizophora mucronata* and *Sonneratia caseolaris* are common in almost all provinces. In the Maldives, mangroves are not estuarine-based and are classified as either 'open' or 'closed' depend on the ecosystem's exposure to the sea (Shadiya *et al*., 2016). Fifteen mangrove species were recorded in the mangrove areas of Maldives (Sivakumar *et al*., 2018) of which *Bruguiera cylindrica* is the dominant species. Recently, *Bruguiera hainesii* a rare and critically endangered mangrove species has been recorded in Maldives and listed in the IUCN Red List (Dryden *et al.*, 2020).

The mangroves of South India and Sri Lanka, and Maldives have at least 242 species in the taxa Actinopterygii, Amphibia, Anthozoa, Aves, Chondrichthyes, Gastropoda, Holothuroidea, Insecta, Magnoliopsida, Mammalia and Reptilia associated with mangrove habitats in the IUCN Red List of Threatened Species (IUCN, 2022). The mudflats around the mangroves of the southern east coast of India support large congregations of birds. Every year about two hundred thousand birds visit these areas, including five species listed in the IUCN Red List of Threatened Species: the Critically Endangered White-bellied Heron (*Ardea insignis*) and Spoon-billed Sandpiper (*Eurynorhynchus pygmeus*); Endangered Spotted Greenshank (*Tringa guttifer*); and Near Threatened Spot-billed Pelican (*Pelecanus philippensis*) and Black-necked Stork (*Ephippiorhynchus asiaticus*) (GIZ, 2023). The Sharptooth Lemon Shark (*Negaprion acutidens*) is an endangered fish species found in the bay of Farukolhu mangrove lagoon in the Maldives (Dryden *et al*., 2020).

A monospecies stand of Avicennia marina in Muthupet, Southeast coast of India (Photo credit: Selvam Vaithilingam)

A young stand of Bruguiera mangrove in the Maldives (Photo credit: Water Solutions, Maldives)

Abiotic Components of the Ecosystem

Mangrove environment can be classified broadly based on three groups of dynamic factors: (i) geophysical (changes in sea-level, climatic conditions and tidal properties of a region); (ii) geomorphic (geomorphologically distinct landscapes due to sedimentation dynamics, dominance of hydrological processes, e.g. wave, tidal or river, and micro-topography of the wetland); and (iii) biological (Thom, 1984). Using machine learning, Worthington *et al*. (2020) created a broad-scale biophysical typology, which is more or less similar to that of Thom's. The geomorphic and sedimentary setting of South India and Sri Lanka, and Maldives, as classified by Worthington *et al.* (2020), is given below:

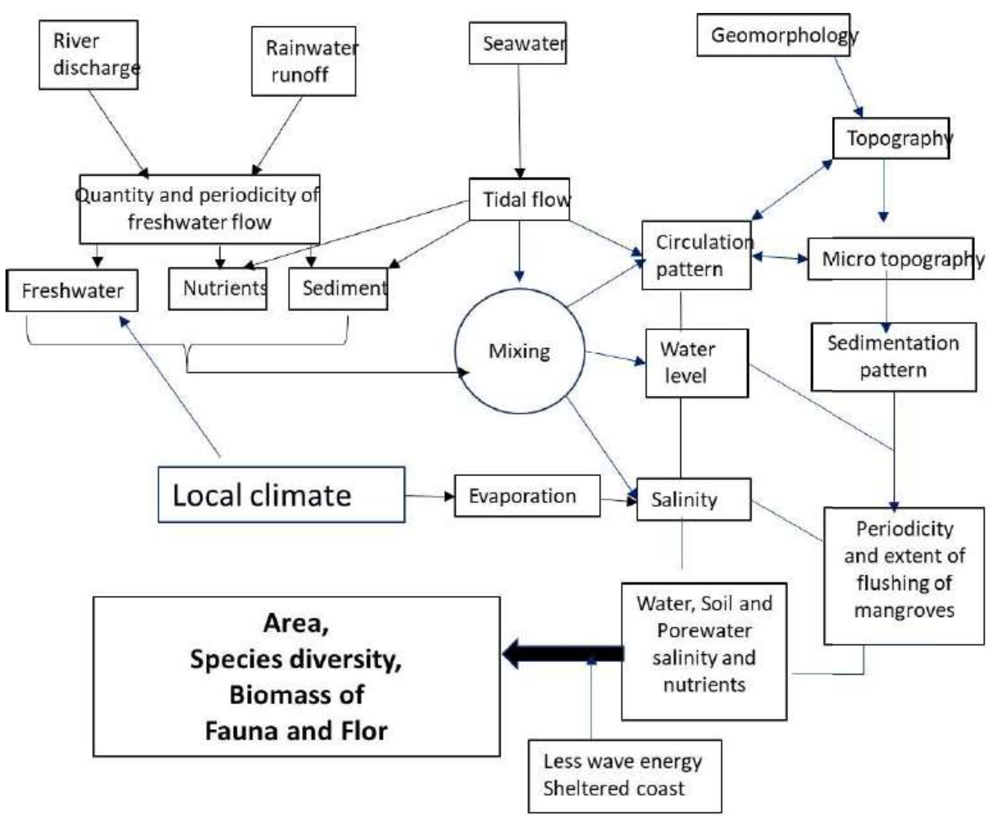
Mangroves	**Geomorphic setting**	**Description**	**Sedimentary setting**
Muthupet mangroves of South India	Deltaic	Fan-shaped plains created by the deposition of large amounts of sediment transported by rivers; Rapid deposition of sediment; mangroves luxuriant in abundant delta	**Terrigenous** (Sediment derived from land. The composition of the sediment depends on the lithology and age of the source rock, as well as the weathering and transport process and history; in a mangrove environment, terrigenous sediment is normally fine
A few of the mangroves in Sri Lanka, e.g. Kalu Ganga mangroves	Estuarine	Funnel-shaped estuaries with bidirectional tidal flows, characterised by large catchment areas and high precipitation input	
Majority of the mangroves in Sri Lanka, e.g. Jaffna and Puttalam mangroves	Lagoonal	Shallow coastal waterbody, intermittently separated from ocean inputs. Usually formed parallel to the shore.	

Many small patches of mangroves south of Muthupet;	Open Coast (but not on bedrock valley)	Sheltered embayment such as Palk Bay and the Gulf of Mannar	texture and rich in organic matter)
Maldives mangroves	Lagoonal	Shallow coastal waterbody, intermittently separated from ocean inputs. Usually formed parallel to the shore	**Carbonate** Platform is made up of accumulated calcareous mud (marl) and peat
	Open coast	Sheltered environments on oceanic islands behind coral reefs and carbonate banks	

The macro-level environmental factors affecting mangroves undergo changes in time and space, and these changes are reflected in the composition and structure of the mangrove ecosystem at the site level (Selvam, 2003). Such changes pertaining to South India and Sri Lanka, and Maldives are described below.

Key processes and interactions

The wealth of mangrove ecosystems in terms of their extent, diversity and biomass of both plants and animals (including fisheries, which are an important component of the mangrove-associated fauna), and the health of the mangroves in terms of hydrological conditions and salinity regime, are determined primarily by i) the quantity and duration of freshwater flow; ii) tidal amplitude; iii) slope of the coast; and iv) protection from high wave energy. These site-level factors interact closely, as illustrated below.



Any changes in these factors influence structure and function of the mangrove ecosystem. For example, as explained elsewhere, a reduction in freshwater flow leads to hypersaline conditions, which, in turn, causes the local extinction of salinity-sensitive species, as in the case of Muthupet (Selvam, 2003). In Sri Lanka, the ecology of mangrove-associated lagoons has changed due to stream flow regulation by constructing dams and trans-basin diversions (Silva *et al*., 2013). Other changes in these processes lead to loss of fish nursery grounds and depletion of fishery resources, and habitat reduction for wildlife, including migratory birds. In the Maldives, open coast mangroves facilitate the deposition of calcareous sediments. (In contrast, where mangroves are physically isolated from the sea, the sediment is deposited from land sources). Since this process has been going on for a long time, the calcareous sediments in the Maldivian mangroves are very deep, measuring about 5.00 m in some areas (Shadiya *et al*., 2016). Mangroves in the Maldives play an important role in fishery management by providing habitats for various fish species. Juveniles of many commercially important species of snappers, jackfish, lethrinids, groupers, goatfish and milkfish are found in large numbers in mangroves that are well-connected to the sea. Juvenile sharptooth lemon sharks (*Negaprion acutidens*), a species classified as Endangered (IUCN, 2022), are observed in the bay at Farukolhu, which harbours a large area of mangroves (Dryden *et al.,* 2020). Hence, any changes in physical processes, such as tidal exchange, will have negative impacts on mangrove-associated fishery resources and biodiversity.

Mangroves act as structural engineers possessing traits such as pneumatophores, salt excretion glands, vivipary, and propagule buoyancy that promote survival and recruitment in poorly aerated, saline, mobile, and tidally inundated substrata. They exhibit high efficiency in nitrogen use and nutrient resorption. Mangroves produce large amounts of detritus (e.g., leaves, twigs, and bark), which is either buried in waterlogged sediments, or consumed by crabs and gastropods, then decomposed further by meiofauna, fungi and bacteria to produce detritus, which becomes available as a protein-rich food source for other consumers in the mangrove and estuarine food web.

Mangrove ecosystems also serve as major blue carbon sinks, incorporating organic matter into sediments and living biomass. Estimation of above and below-ground and soil carbon stocks of five important mangrove forests in Sri Lanka (Rekawa, Puttalam-Kalpitiya, Pambala-Chilaw, Batticaloa and Negombo), which are situated in the three major climate zones (dry, intermediate and wet), ranged from 75.5 to 189.1 Mg C ha^{-1}, 7.9 to 14.3 Mg C ha^{-1}, and 643.6 to 1253.6 Mg C ha^{-1} respectively. The study also showed that the soil comprised 83-90% of the total mangrove carbon stocks at all sites, highlighting the large potential for release into the atmosphere as carbon dioxide if these habitats are disturbed (Cooray *et al*., 2021). In the mangroves of Kerala, which are in a wet zone, the mean total ecosystem carbon is 218.98 ± 169.86 Mg C ha^{-1}, which is equivalent to 803.66 ± 621.47 Mg CO_2 ha^{-1}. Further, 88% of the estimated ecosystem carbon stock was represented by vegetation biomass and 22% by the soil carbon stock (Sreelekshmi *et al*., 2022).

3. Ecosystem Threats and vulnerabilities

Main threatening process and pathways to degradation

Mangrove deforestation arises from various factors, including changes in biophysical conditions due to over-harvesting, unsound management practices, aquaculture, urbanization and associated coastal development, reduction in freshwater flow, and pollution stemming from domestic, industrial, and agricultural sources. The location of mangrove forests within intertidal areas also renders them vulnerable to sea-level rise as a result of climate change. Tropical storms can damage mangrove forests through direct defoliation and destruction of trees, as well as through the mass mortality of animal communities within the ecosystem.Four major threats may lead to the collapse of the mangrove ecosystem in South India, Sri Lanka, and Maldives: i) reduced freshwater flow and increased salinity; ii) changes in sedimentation dynamics; iii) conversions to other land uses; and iii) climate change especially storm surges, flood and sea-level rise.

A complex interaction of reduced freshwater flow and increased salinity affects the mangroves of the southernmost east coast of India located in the deltaic region of the Cauvery River (Selvam, 2020). The catchment area of this delta is situated in two monsoon regimes. The upper catchment area receives rainfall during summer (July to September), and the lower catchment area gets rain during winter (October to December). The Cauvery Basin is highly populated, and agriculture is the primary economic occupation. To improve water resources, 96 dams, 10 barrages, 16 weirs/anicuts, and nine lift irrigation projects have been constructed in this basin (MoWR, 2014). As a result, the quantity and duration of freshwater flowing into the mangroves during the summer and winter monsoons have reduced drastically. In addition, the mangrove wetland area is not well-flushed by tidal water due to the low tidal amplitude. Consequently, tidal water reaching the mangroves remains stagnant in depressions created by biophysical changes from past clear-felling management practices. The stagnant tidal water evaporates, leading to the development of hypersaline conditions. Due to reduced freshwater flow, the hypersaline conditions persist, leading to a) local extinction of less salt-tolerant mangroves; and b) gradual reduction in mangrove cover (Tissot, 1987; Kathiresan, 2000; Selvam, 2003).

Currently, mangrove cover in this and adjoining mangrove patches is restored by establishing artificial canals to increase tidal flushing. However, both the restored and remaining natural mangroves will survive only if they receive sufficient freshwater discharge. Another important factor that causes degradation is the high rate of sedimentation. Palk Bay, which supplies tidal water to the mangroves on India's southern east coast, is one of the major sediment sinks. As a result, large quantities of sediment are brought into the mangroves and deposited in the waterways, including lagoons and creeks, making them shallow. This causes faster water evaporation, which contributes to hyper salinity (NIOT, 2005).

Sedimentation of the waterways that connect mangroves and lagoons is a serious issue in Maldives and several estuaries and lagoons in Sri Lanka that support mangroves have decreased gradually in size. For example, due to sedimentation, the effective water area in Negombo Lagoon has diminished by 791 hectares over a period of two decades (NRESA, 1991). Conversion of mangroves to other land uses is another important reason for the degradation of mangroves in South India, Sri Lanka, and the Maldives. The primary cause of the loss of mangroves in the southern west coast of India is the conversion of mangrove areas for paddy cultivation and shrimp farming. Although India and Sri Lanka have strict legislation to protect mangroves from conversion to other land uses, mangroves that are located on lands that are privately owned, and on lands that are not owned by the Forest Department, face the problem of conversion to various land uses, as in the case of Kerala on the western south coast of India. In some areas, the mangroves are converted to develop large-scale infrastructure and urban projects, or for coconut plantations and shrimp culture (Veettil *et al*., 2023).

Land-filling for house construction is taking place extensively in the mangrove-supporting lagoons in Sri Lanka, and this has been identified as one of the major threats to the lagoon environment and the associated mangroves (Silva *et al*., 2013). An irrigation project has caused heavy siltation and reduction of salinity in Kalametiya Lagoon the lagoon, resulting in about 86% of the water surface area being taken over by *Sonneratia caseolaris* and *Typha angustifolia* as the dominant riparian vegetation. Water quality in the remaining water body has also deteriorated as evident by increased acidity, reduced dissolved oxygen and increased ammonium content. If the present trend continues, the remaining water surface could be lost in the near future (Madarasinghe *et al*., 2020).

Hotel construction in Rekawa mangrove forest (Photo credit: K. A. Sunanda Kodikara)

Another factor that threatens the mangroves of South India and Sri Lanka are invasive species. In Southern India, *Prosopis juliflora*, an exotic species of shrub (Family Fabaceae) that can tolerate a wide range of environmental conditions, including high temperature, low freshwater availability and high salinity, is making entry into mangroves gradually, though currently they are present on a large scale in the periphery of mangroves. In Sri Lanka, *Acrostichum aureum and Acacia auriculiformis* have invaded many mangroves. *Acrostichum aureum* is considered a problematic species because it seems to suppress the spread and growth of mangroves. *A. auriculiformis* has become the dominant species in the back mangroves of many of the mangroves of Sri Lanka, occurring with true mangroves. In these areas, the highest sapling and seedling densities are recorded and a high contribution of *A. auriculiformis* to relative densities and relative dominance supports the competitive domination of the Acacia plants over mangroves (Kodikara *et al.,* 2022).

Coconut plant burning inside a mangrove forest (Photo credit: K. A. Sunanda Kodikara)

Sedimentation is a serious problem affecting most of the mangroves of Maldives (Photo credit: Water Solutions, Maldives)

Mass mortality of Avicennia marina in Muthupet, caused by a complex interaction of reduced freshwater flow, sedimentation and inadequate tidal flushing (Photo credit: Selvam Vaithilingam)

Impact of 2018 Gaja cyclone in 2018 on Muthupet mangroves: trees were broken or defoliated, and some were uprooted.(Photo credit: Selvam Vaithilingam)

Definition of the collapsed state of the ecosystem

Mangroves, acting as structural engineers, possess specialized traits that facilitate high nitrogen use efficiency and nutrient resorption, influencing critical processes and functions within their ecosystem. Ecosystem collapse is recognised when the tree cover of diagnostic true mangrove species dwindles to zero, indicating complete loss (100%).

Mangrove ecosystems exhibit remarkable dynamism, with species distributions adapting to local shifts in sediment distribution, tidal patterns, and variations in local inundation and salinity gradients. Disruptive processes can trigger shifts in this dynamism, potentially leading to ecosystem collapse. Ecosystem collapse may manifest through the following mechanisms: a) restricted recruitment and survival of diagnostic true mangroves due to adverse climatic conditions (e.g., low temperatures); b) alterations in rainfall, river inputs, waves, and tidal currents that destabilize and erode soft sediments, hindering recruitment and growth; c) shifts in rainfall patterns and tidal flushing altering salinity stress and nutrient loadings, impacting overall survival.

Mangroves in this ecoregion will be affected severely by increased temperature and reduced rainfall due to climate change during the summer season. For example, it is predicted that rainfall during the summer on the southeast coast of India will be reduced by 10%, while average temperatures will increase by 2.1°C. This will increase the evaporation of soil water and increase soil and water salinity, adding to already existing hypersaline conditions. This may lead to a substantial loss in mangroves (ICEM, 2023). There will be an increased frequency of cyclones, which will also cause loss of mangroves. For example, the Gaja cyclone (November 2018) caused extensive damage to mangroves in Muthupet, reducing mangrove forest cover from 16 km^2 in 2017 to 13 km^2 in 2019 (FSI, 2019). Although mangrove forests can recoup naturally, repeated cyclones may lead to cumulative loss.

In the case of the Maldives, climate change-induced impacts vary across the archipelago due to geophysical settings and climatic controls. Cyclone hazards are highest in the north and very low in the south Maldives due to the greater proximity of northern latitudes to the cyclone belt. Hence, the possibility of storm surges associated with the cyclones is also highest in the north. Swell waves are more prominent in the southern and western islands of Maldives due to the proximity to the Southern Indian Ocean and the predominant south-westerly approach of the swell waves. However, nearly 80% of the Maldives' land mass is less than 1m above sea level, and thus, the Maldives and its mangroves are acutely vulnerable to sea-level rise (UNDP, 2019).

Threat Classification

IUCN Threat Classification (version 3.3, IUCN-CMP, 2022) relevant to mangroves of the South India, Sri Lanka, and Maldives province:

1. Residential & commercial development
- 1.1 Housing & urban areas
- 1.2 Commercial & industrial areas

2. Agriculture & aquaculture
- 2.3 Livestock farming & ranching
    - 2.3.2 Small-holder grazing, ranching or farming
- 2.4 Marine & freshwater aquaculture
    - 2.4.1 Subsistence/artisanal aquaculture

4. Transportation & service corridors
- 4.1 Roads & railroads

5. Biological resource use
- 5.3 Logging & wood harvesting
    - 5.3.1 Intentional use: subsistence/small scale (species being assessed is the target [harvest]
- 5.4 Fishing & harvesting aquatic resources
    - 5.4.1 Intentional use: subsistence/small scale (species being assessed is the

6. Human intrusions & disturbance

- 6.1 Recreational activities
- 6.2 War, civil unrest & military exercises
- 6.3 Work & other activities

7. Natural system modifications

- 7.2 Dams & water management/use
    - 7.2.1 Abstraction of surface water (domestic use)
    - 7.2.2 Abstraction of surface water (commercial use)
    - 7.2.3 Abstraction of surface water (agricultural use)
    - 7.2.5 Abstraction of ground water (domestic use)
    - 7.2.6 Abstraction of ground water (commercial use)
    - 7.2.7 Abstraction of ground water (agricultural use)
    - 7.2.9 Small dams
    - 7.2.10 Large dams
- 7.3 Other ecosystem modifications

8. Invasive & other problematic species, genes & diseases

- 8.1 Invasive non-native/alien species/diseases
    - 8.1.2 Named species
- 8.2 Problematic native species/diseases

9. Pollution

- 9.1 Domestic & urban waste water
    - 9.1.1 Sewage
    - 9.1.2 Run-off
- 9.3 Agricultural & forestry effluents
    - 9.3.1 Nutrient loads
    - 9.3.2 Soil erosion, sedimentation
    - 9.3.3 Herbicides & pesticides
- 9.4 Garbage & solid waste

11. Climate change & severe weather

- 11.1 Habitat shifting & alteration
- 11.4 Storms & flooding
- 11.5 Other impacts (sea-level rise)

4. Ecosystem Assessment

Criterion A: Reduction in Geographic Distribution

Subcriterion A1 measures the trend in ecosystem extent during the last 50-year time window. Unfortunately, there is currently no common regional dataset that provides information for the entire target area in 1970. However, country-level estimates of mangrove extent can be used to extrapolate the trend between 1970 and 2020.

To estimate mangrove area in 1970 for each country within the province, we compiled reliable published sources that contain information on mangrove area estimates close to 1970 (see appendix 3). These estimates were then used to interpolate the mangrove area in 1970 in each country. By summing up these estimates, we calculated the total mangrove area in the province. We only considered the percentage of each country's total mangrove area located within the province. The estimated values for 1970 should be considered only indicative (see appendix 3 for further details of the methods and limitations).

To evaluate the mangrove area in 2020, we employed two methods. First, we compiled estimates from national statistics and published articles. Second, we calculated the province area using the Global Mangrove Watch (GMW v3.0) spatial dataset. The mangrove area in the province was corrected for both omission and commission errors, utilizing the equations in Bunting *et al.*, (2022).

The analysis of sub-criterion A1 (Annex 3), which examines the trend in ecosystem extent during the last 50-years (1970-2020), reveals an expansion in the mangrove province of "South India, Sri Lanka, and Maldives". Estimates derived from national statistics and literature indicate a ~58% increase, while those from the GMW suggest a 100% increase (see table below). Both southern India and Sri Lanka showed increased mangrove area compared to 1970. Consequently, the ecosystem is assessed as **Least Concern (LC)** under Subcriterion A1.

Mangroves of the South India, Sri Lanka, and Maldives		Area 2020 (Km^2)	Area 1970 (Km^2)	Net area Change (Km^2)	% Net Area Change	Rate of change (%/year)
	High estimate	249.2**	124.8*	124.4	99.6	4.2
	Lower estimate	197.1*	124.8*	72.2	57.8	2.4

** Details on the methods and references used to estimate the mangrove area in 1970 and 2020 are listed in appendix 3.*
*** Estimated mangrove area based on the Global Mangrove Watch Version 3 (GMW v3.0) dataset.*

Subcriterion A2 measures the change in ecosystem extent in any 50-year period, including from the present to the future: To evaluate recent mangrove area changes we used the most recent version of the Global Mangrove Watch (GMW v3.0) spatial dataset, which includes a time series from 1996 to 2020. Based on the GMW dataset, "The South India, Sri Lanka, and Maldives" mangrove province shows a net area change of -26.8% between 1996 and 2020 (Bunting *et al.,* 2022). This value reflects the offset between areas gained (+ 0.1%/year) and lost (- 1.2%/year). The largest decrease in mangrove area in this time series occurred between 1996 and 2010 (Figure 2). This period coincides with the period of high mangrove deforestation in Asia during the 90s (Giri *et al.,* 2008), followed by significant natural disasters such as the 2004 Indian Ocean Tsunami (Sri Lanka section) and 2000's cyclones (Giri *et al* 2008, 2015, Veettil, 2023).

Applying a linear regression to the area estimations between 1996 and 2020 we obtained a rate of change in the mangrove forest area of -1.1%/year (Figure 2). Assuming this trend continues in the future, it is predicted that the extent of mangroves in the South India, Sri Lanka, and Maldives province will change by -49.0% from 1996 to 2046; by -69.2% from 1996 to 2070; but by -58.0% from 2020 to 2070.

However, the mangrove area based on national statistics for a similar period shows a different trend (Annex 3 Table b). We find significant differences in the baseline area (1996), which would result in a completely different outcome compared to the 2020 area. According to FSI (2021), the South India portion in 1997 was 21 km^2 compared to 80.5 km^2 for 1996 based on GMW. Based on FSI (2021) and national data, the province's area rate of change per year is (-0.20%/year), with net area change of -4.8% and a change of -9.9% over 50 years.

The discrepancies between the predicted changes highlight the uncertainty in assessing the vulnerability of the South India, Sri Lanka, and Maldives mangrove ecosystem. Considering the potential impact shown in both datasets the ecosystem is assessed as **Vulnerable (VU) with a plausible range between Least**

Concern to Endangered (LC - EN), under Subcriterion A2.

Subcriterion A3 measures changes in mangrove area since 1750. Unfortunately, there are no reliable data on the mangrove extent for the entire province during this period, and therefore the Red Sea and Gulf of Aden mangrove ecosystem is classified as **Data Deficient (DD)** for this subcriterion.

Overall, the ecosystem is assessed as **Vulnerable (VU)** under criterion A.

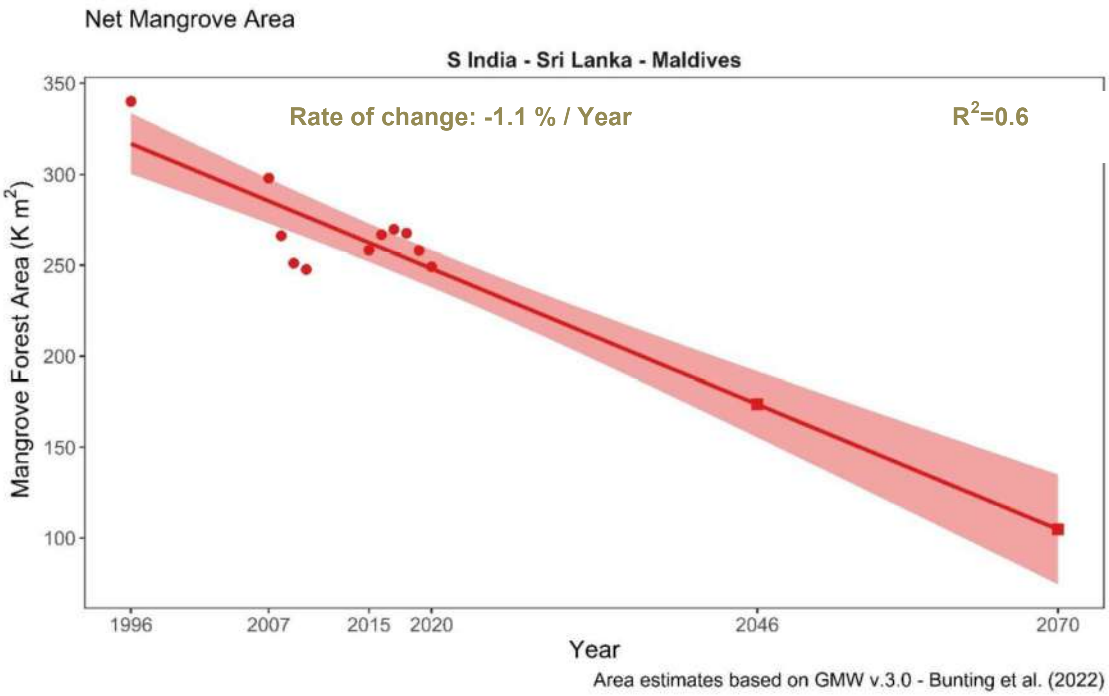


Figure 2. Projected extent of the South India, Sri Lanka, and Maldives mangrove ecosystem to 2070. Circles represent the province mangrove area between 1996 and 2020 based on the GMW v3.0 dataset and equations in Bunting *et al*., (2022). The solid line and shaded area are the linear regression and 95% confidence intervals. Squares show the South India, Sri Lanka, and Maldives province predicted mangrove area for 2046 and 2070. It is important to note that an exponential model (proportional rate of decline) did not give a better fit to the data (R^2 = 0.6). The estimated mangrove area in the province (and in the corresponding countries) was corrected for both omission and commission errors, utilizing the equations in Bunting et al. (2022).

Criterion B: Restricted Geographic Distribution

Criterion B measures the risk of ecosystem collapse associated with restricted geographical distribution, based on standard metrics (Extent of Occurrence EOO, Area of Occupancy AOO, and Threat-defined locations). These parameters were calculated based on the 2020 South India, Sri Lanka, and Maldives province mangrove extent (GMW v.3).

Province	Extent of Occurrence EOO (Km^2)	Area of Occupancy (AOO) >1%	Criterion B
The South India, Sri Lanka, and Maldives	641337.6	58	**LC**

For 2020, AOO and EOO were measured as 58 grid cells 10 x 10 km and 641337.6 km^2, respectively (Figure 3). From total of 166 cells, excluding from the AOO those grid cells that contain patches of mangrove forest that account for less than 1% of the grid cell area, (< 1 Km^2), the AOO is measured as **58, 10 x 10 km grid cells** (Figure 3, red grids). Therefore, Red Sea and Gulf of Aden mangroves assessed as **Least Concern** (**LC**) under subcriteria B1 and B2.

Considering the very high number of threat-defined-locations, there is no evidence of plausible catastrophic threats leading to potential disappearance of mangroves across their extent. As a result, the South India, Sri Lanka, and Maldives mangrove ecosystem is assessed as **Least Concern (LC)** under criterion B3.

Overall, the ecosystem is assessed as **Least Concern (LC)** under criterion B.

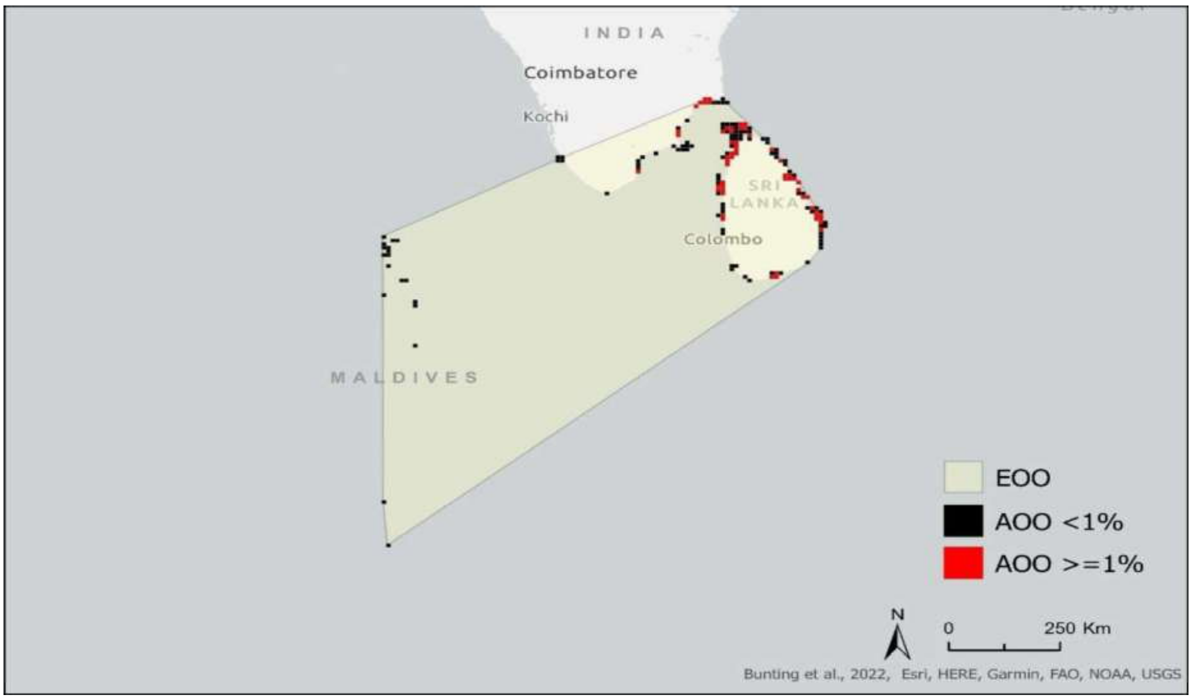


Figure 3. The South India and Sri Lanka, and Maldives mangrove Extent of Occurrence (EOO) and Area of Occupancy (AOO) in 2020. Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022). The red 10 x 10 km grids (n=58) are more than 1% covered by the ecosystem, and the black grids <1% (n= 90).

Criterion C: Environmental Degradation

Criterion C measures the environmental degradation of abiotic variables necessary to support the ecosystem.

Subcriterion C1 measures environmental degradation over the past 50 years: There are no reliable data to evaluate this subcriterion for the entire province, and therefore the South India, Sri Lanka, and Maldives mangrove ecosystem is classified as **Data Deficient (DD)** for subcriterion C1.

Subcriterion C2 measures environmental degradation in the future, or over any 50-year period, including from the present. In this context, the impact of future sea-level rise (SLR) on mangrove ecosystems was assessed by adopting the methodology presented by Schuerch *et al.* (2018). The published model was designed to calculate both absolute and relative change in the extent of wetland ecosystems under various regional SLR scenarios (i.e. medium: RCP 4.5 and high: RCP 8.5), with consideration for sediment accretion. Therefore, the Schuerch *et al*. (2018) model was applied to the South India, Sri Lanka, and

Maldives mangrove ecosystem boundary, with spatial extent based on Giri *et al*. (2011) and assuming mangrove landward migration was not possible.

According to the results, under an extreme sea-level rise scenario of a 1.1 m rise by 2100, the projected submerged area is ~ -82.4% by 2060, which is above the 80% risk threshold. Therefore, considering that no mangrove recruitment can occur in a submerged system (100% relative severity), but that -82.4% of the ecosystem extent will be affected by SLR, the South India, Sri Lanka, and Maldives mangrove ecosystem is assessed as **Critically Endangered (CR)** for subcriterion C2.

Subcriterion C3 measures change in abiotic variables since 1750. There is a lack of reliable historic data on environmental degradation covering the entire province, and therefore the South India, Sri Lanka, and Maldives ecoregion is classified as **Data Deficient (DD)** for this subcriterion.

Overall, the ecosystem is assessed as **Critically Endangered (CR)** under criterion C.

Criterion D: Disruption of biotic processes or interactions

The global mangrove degradation map developed by Worthington and Spalding (2018) was used to assess the level of biotic degradation in the South India, Sri Lanka, and Maldives province. This map is based on degradation metrics calculated from vegetation indices (NDVI, EVI, SAVI, NDMI) using Landsat time series (≈2000 and 2017). These indices represent vegetation greenness and moisture condition.

Mangrove degradation was calculated at a pixel scale (30 m resolution), on areas intersecting with the 2017 mangrove extent map (GMW v2). Mangrove pixels were classified as degraded if two conditions were met: 1) at least 10 out of 12 degradation indices showed a decrease of more than 40% compared to the previous period; and 2) all twelve indices did not recover to within 20% of their pre-2000 value (detailed methods and data are available at: maps.oceanwealth.org/mangrove-restoration/). The decay in vegetation indices has been used to identify mangrove degradation and abrupt changes, including mangrove die-back events, clear-cutting, fire damage, and logging; as well as to track mangrove regeneration (Lovelock *et al.,* 2017; Santana, 2018; Murray *et al.,* 2020; Aljahdali *et al.,* 2021; Lee *et al.,* 2021). However, it is important to consider that changes observed in the vegetation indices can also be influenced by data artifacts (Akbar *et al.,* 2020). Therefore, a relative severity level of more than 50%, but less than 80%, was assumed.

The results from this analysis show that over a period of 17 years (~2000 to 2017), 3.25% of the South India, Sri Lanka, and Maldives mangrove area is classified as degraded, resulting in an average annual rate of degradation of 0.19%. Assuming this trend remains constant, +9.5% of the South India, Sri Lanka, and Maldives mangrove area will be classified as degraded over a 50-year period. Since less than 30% of the ecosystem will meet the category thresholds for criterion D, the South India, Sri Lanka, and Maldives mangrove province is assessed as **Least Concern** (**LC)** under subcriterion D2b.

No data were found to assess the disruption of biotic processes and degradation over the past 50 years (subcriterion D1) or since 1750 (subcriterion D3). Thus, both subcriteria are classified as **Data Deficient (DD).**

Overall, the South India, Sri Lanka, and Maldives mangrove ecosystem remains **Least Concern (LC)** under criterion D.

Criterion E: Quantitative Risk

No model was used to quantitatively assess the risk of ecosystem collapse for this ecosystem; hence criterion E was **Not Evaluated (NE)**.

5. Summary of the Assessment

CRITERION			
A. Reduction in Geographic Distribution	A1 Past 50 years	A2 Future or any 50y period	A3 Historical (1750)
	LC	VU	DD
B. Restricted Geo. Distribution	B1 Extent of Occurrence	B2 Area of Occupancy	B3 # Threat-defined Locations < 5?
	LC	LC	LC
C. Environmental Degradation	C1 Past 50 years (1970)	C2 Future or any 50y period	C3 Historical (1750)
	DD	CR	DD
D. Disruption of biotic processes	D1 Past 50 years (1970)	D2 Future or Any 50y period	D3 Historical (1750)
	DD	LC	DD
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

CR= Critically Endangered; VU= Vulnerable; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated;

Overall, the status of the South India, Sri Lanka, and Maldives mangrove ecosystem is assessed as **Critically Endangered (CR).**

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6. Appendices

1. List of Key Mangrove Species

List of plant species considered true mangroves according to Red List of Threatened Species (RLTS) spatial data (IUCN, 2022). We included species whose range maps intersected with the boundary of the marine provinces/ecoregions described in the distribution section.

Class	Order	Family	Scientific name	RLTS category
Polypodiopsida	Polypodiales	Pteridaceae	*Acrostichum aureum*	LC
Magnoliopsida	Ericales	Primulaceae	*Aegiceras corniculatum*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia marina*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia officinalis*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera cylindrica*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera gymnorhiza*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera parviflora*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Ceriops decandra*	NT
Magnoliopsida	Malpighiales	Rhizophoraceae	*Ceriops tagal*	LC
Magnoliopsida	Malpighiales	Euphorbiaceae	*Excoecaria agallocha*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Kandelia candel*	LC
Magnoliopsida	Myrtales	Combretaceae	*Lumnitzera littorea*	LC
Magnoliopsida	Myrtales	Combretaceae	*Lumnitzera racemosa*	LC
Liliopsida LC	Arecales	Arecaceae	*Nypa fruticans*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora apiculata*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora mucronata*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia alba*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia apetala*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia caseolaris*	LC
Magnoliopsida	Sapindales	Meliaceae	*Xylocarpus granatum*	LC
Magnoliopsida	Gentianales	Rubiaceae	Scyphiphora hydrophylacea	LC

2. List of Associated Species

List of taxa that are associated with mangrove habitats in the Red List of Threatened Species (RLTS) database (IUCN, 2022). We included only species with entries for Habitat 1.7: "Forest - Subtropical/Tropical Mangrove Vegetation Above High Tide Level" or Habitat 12.7 for "Marine Intertidal - Mangrove Submerged Roots", and with suitability recorded as "Suitable", with "Major Importance" recorded as "Yes", and any value of seasonality except "Passage". The common names are those shown in the RLTS, except common names in brackets, which are from other sources.

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Gobiiformes	Gobiidae	*Oligolepis acutipennis*	LC	Pointed-fin goby
Actinopterygii	Gobiiformes	Gobiidae	*Redigobius balteatus*	LC	Girdled goby
Actinopterygii	Perciformes	Sparidae	*Acanthopagrus berda*	LC	Picnic seabream
Actinopterygii	Gobiiformes	Gobiidae	*Acentrogobius audax*	LC	(Mangrove goby)
Actinopterygii	Albuliformes	Albulidae	*Albula glossodonta*	VU	Shortjaw bonefish
Actinopterygii	Perciformes	Ambassidae	*Ambassis buruensis*	DD	Buru glassfish
Actinopterygii	Perciformes	Ambassidae	*Ambassis interrupta*	LC	Long-spined glassfish

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Perciformes	Ambassidae	*Ambassis nalua*	LC	Scalloped perchlet
Actinopterygii	Perciformes	Ambassidae	*Ambassis urotaenia*	LC	Bleeker's glass perchlet
Actinopterygii	Tetraodontiformes	Monacanthidae	*Anacanthus barbatus*	LC	Bearded leatherjacket
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron hispidus*	LC	White-spotted puffer
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron immaculatus*	LC	Immaculate puffer
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron reticularis*	LC	Reticulated pufferfish
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron stellatus*	LC	Stellate puffer
Actinopterygii	Gobiiformes	Gobiidae	*Asterropteryx semipunctata*	LC	Star-finned goby
Actinopterygii	Atheriniformes	Atherinidae	*Atherinomorus lacunosus*	LC	Hardyhead silverside
Actinopterygii	Perciformes	Carangidae	*Atule mate*	LC	Yellowtail scad
Actinopterygii	Gobiiformes	Eleotridae	*Bostrychus sinensis*	LC	Four-eyed sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Butis butis*	LC	Crimson-tipped gudgeon
Actinopterygii	Gobiiformes	Eleotridae	*Butis gymnopomus*	LC	Striped crazy fish
Actinopterygii	Gobiiformes	Eleotridae	*Butis koilomatodon*	LC	Marblecheek sleeper
Actinopterygii	Gobiiformes	Gobiidae	*Caragobius urolepis*	LC	Scaleless worm goby
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Chelonodontops patoca*	LC	Milkspotted puffer
Actinopterygii	Clupeiformes	Engraulidae	*Coilia neglecta*	LC	Neglected grenadier anchovy
Actinopterygii	Gobiiformes	Eleotridae	*Eleotris fusca*	LC	Brown spinecheek gudgeon
Actinopterygii	Elopiformes	Elopidae	*Elops machnata*	LC	Na
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus coeruleopunctatus*	LC	Whitespotted grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus coioides*	LC	Orange-spotted grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus malabaricus*	LC	Malabar grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus tauvina*	DD	Greasy grouper
Actinopterygii	Perciformes	Leiognathidae	*Eubleekeria splendens*	LC	Splendid ponyfish
Actinopterygii	Gobiiformes	Gobiidae	*Exyrias puntang*	LC	Puntang goby
Actinopterygii	Perciformes	Leiognathidae	*Gazza minuta*	LC	Toothed ponyfish
Actinopterygii	Perciformes	Gerreidae	*Gerres erythrourus*	LC	Deep-bodied mojarra
Actinopterygii	Perciformes	Gerreidae	*Gerres filamentosus*	LC	Whipfin mojarra
Actinopterygii	Syngnathiformes	Syngnathidae	*Hippichthys cyanospilos*	LC	Bluespeckled pipefish
Actinopterygii	Syngnathiformes	Syngnathidae	*Hippichthys heptagonus*	LC	Reticulated freshwater pipefish
Actinopterygii	Syngnathiformes	Syngnathidae	*Hippichthys penicillus*	LC	Beady pipefish
Actinopterygii	Syngnathiformes	Syngnathidae	*Hippichthys spicifer*	LC	Bellybarred pipefish
Actinopterygii	Gobiiformes	Gobiidae	*Istigobius ornatus*	LC	Ornate goby

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Perciformes	Sciaenidae	*Johnius belangerii*	LC	Belanger's croaker
Actinopterygii	Perciformes	Sciaenidae	*Johnius borneensis*	LC	Hammer croaker
Actinopterygii	Perciformes	Sciaenidae	*Johnius carouna*	LC	Caroun croaker
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Lagocephalus lunaris*	LC	Lunartail puffer
Actinopterygii	Perciformes	Leiognathidae	*Leiognathus equulus*	LC	Common ponyfish
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus harak*	LC	Thumbprint emperor
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus nebulosus*	LC	Spangled emperor
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus ornatus*	LC	Ornate emperor
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus semicinctus*	LC	Black-spot emperor
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus argentimaculatus*	LC	Mangrove red snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus ehrenbergii*	LC	Blackspot snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulviflamma*	LC	Dory snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulvus*	LC	Blacktail snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus johnii*	LC	John's snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus sebae*	LC	Red emperor snapper
Actinopterygii	Elopiformes	Megalopidae	*Megalops cyprinoides*	DD	Indo-pacific tarpon
Actinopterygii	Perciformes	Monodactylidae	*Monodactylus argenteus*	LC	Silver moony
Actinopterygii	Gobiiformes	Gobiidae	*Mugilogobius fuscus*	LC	Dusky mangrove goby
Actinopterygii	Gobiiformes	Gobiidae	*Mugilogobius mertoni*	LC	Merton's mangrove goby
Actinopterygii	Gobiiformes	Gobiidae	*Mugilogobius rambaiae*	LC	Queen of siam goby
Actinopterygii	Siluriformes	Bagridae	*Mystus gulio*	LC	(Long whisker cat fish)
Actinopterygii	Clupeiformes	Clupeidae	*Nematalosa nasus*	LC	Bloch's gizzard shad
Actinopterygii	Perciformes	Pomacentridae	*Neopomacentrus taeniurus*	DD	Freshwater damsel
Actinopterygii	Perciformes	Sciaenidae	*Nibea maculata*	LC	Blotched croaker
Actinopterygii	Perciformes	Labridae	*Novaculichthys macrolepidotus*	LC	Green-banner wrasse
Actinopterygii	Perciformes	Blenniidae	*Omobranchus ferox*	LC	Gossamer blenny
Actinopterygii	Perciformes	Blenniidae	*Omobranchus hikkaduwensis*	VU	Na
Actinopterygii	Perciformes	Blenniidae	*Omobranchus smithi*	VU	Na
Actinopterygii	Perciformes	Apogonidae	*Ostorhinchus lateralis*	LC	Humpback cardinal
Actinopterygii	Perciformes	Sciaenidae	*Otolithes cuvieri*	LC	Lesser tiger toothed croaker
Actinopterygii	Perciformes	Sciaenidae	*Panna heterolepis*	LC	Hooghly croaker
Actinopterygii	Gobiiformes	Gobiidae	*Parachaeturichthys polynema*	LC	Lancet-tail goby
Actinopterygii	Clupeiformes	Pristigasteridae	*Pellona ditchela*	LC	Indian pellona
Actinopterygii	Gobiiformes	Gobiidae	*Periophthalmus argentilineatus*	LC	Barred mudskipper
Actinopterygii	Gobiiformes	Gobiidae	*Periophthalmus kalolo*	LC	Kalolo mudskipper

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Mugiliformes	Mugilidae	*Planiliza subviridis*	LC	Greenback mullet
Actinopterygii	Perciformes	Ephippidae	*Platax orbicularis*	LC	Orbiculate batfish
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus gibbosus*	LC	Brown sweetlips
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus pictus*	LC	Trout sweetlips
Actinopterygii	Siluriformes	Ariidae	*Plicofollis dussumieri*	LC	Blacktip sea catfish
Actinopterygii	Perciformes	Polynemidae	*Polydactylus microstomus*	LC	Small-mouthed threadfin
Actinopterygii	Gobiiformes	Gobiidae	*Psammogobius biocellatus*	LC	Sleepy goby
Actinopterygii	Gobiiformes	Gobiidae	*Pseudogobius melanosticta*	LC	Black-spotted goby
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Pseudorhombus arsius*	LC	Largetooth flounder
Actinopterygii	Clupeiformes	Clupeidae	*Sardinella albella*	LC	White sardinella
Actinopterygii	Aulopiformes	Synodontidae	*Saurida nebulosa*	LC	Clouded lizardfish
Actinopterygii	Perciformes	Scatophagidae	*Scatophagus argus*	LC	Spotted scat
Actinopterygii	Perciformes	Siganidae	*Siganus vermiculatus*	LC	Vermiculated spinefoot
Actinopterygii	Clupeiformes	Engraulidae	*Stolephorus andhraensis*	LC	Andhra anchovy
Actinopterygii	Aulopiformes	Synodontidae	*Synodus sageneus*	LC	Speartoothed grinner
Actinopterygii	Gobiiformes	Gobiidae	*Taenioides cirratus*	DD	Whiskered eel goby
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Takifugu oblongus*	LC	Lattice blaasop
Actinopterygii	Clupeiformes	Engraulidae	*Thryssa baelama*	LC	Baelama anchovy
Actinopterygii	Clupeiformes	Engraulidae	*Thryssa mystax*	LC	Moustached thryssa
Actinopterygii	Perciformes	Toxotidae	*Toxotes jaculatrix*	LC	Banded archerfish
Actinopterygii	Gobiiformes	Gobiidae	*Trypauchen vagina*	LC	Burrowing goby
Actinopterygii	Anguilliformes	Muraenidae	*Uropterygius concolor*	LC	Brown moray eel
Actinopterygii	Perciformes	Apogonidae	*Yarica hyalosoma*	LC	Mangrove cardinalfish
Amphibia	Anura	Bufonidae	*Duttaphrynus melanostictus*	LC	Black-spectacled toad
Amphibia	Anura	Dicroglossidae	*Euphlyctis hexadactylus*	LC	Indian green frog
Anthozoa	Scleractinia	Siderastreidae	*Siderastrea savignyana*	LC	Na
Aves	Accipitriformes	Accipitridae	*Accipiter virgatus*	LC	Besra
Aves	Charadriiformes	Scolopacidae	*Actitis hypoleucos*	LC	Common sandpiper
Aves	Passeriformes	Aegithinidae	*Aegithina tiphia*	LC	Common iora
Aves	Coraciiformes	Alcedinidae	*Alcedo atthis*	LC	Common kingfisher
Aves	Coraciiformes	Alcedinidae	*Alcedo meninting*	LC	Blue-eared kingfisher
Aves	Psittaciformes	Psittacidae	*Alexandrinus krameri*	LC	Rose-ringed parakeet
Aves	Gruiformes	Rallidae	*Amaurornis phoenicurus*	LC	White-breasted waterhen
Aves	Suliformes	Anhingidae	*Anhinga melanogaster*	NT	Oriental darter
Aves	Caprimulgiformes	Apodidae	*Apus affinis*	LC	Little swift
Aves	Pelecaniformes	Ardeidae	*Ardea cinerea*	LC	Grey heron

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Pelecaniformes	Ardeidae	*Ardea intermedia*	LC	Intermediate egret
Aves	Pelecaniformes	Ardeidae	*Ardea purpurea*	LC	Purple heron
Aves	Pelecaniformes	Ardeidae	*Ardeola grayii*	LC	Indian pond-heron
Aves	Pelecaniformes	Ardeidae	*Butorides striata*	LC	Green-backed heron
Aves	Cuculiformes	Cuculidae	*Centropus sinensis*	LC	Greater coucal
Aves	Coraciiformes	Alcedinidae	*Ceryle rudis*	LC	Pied kingfisher
Aves	Charadriiformes	Charadriidae	*Charadrius dubius*	LC	Little ringed plover
Aves	Charadriiformes	Charadriidae	*Charadrius mongolus*	LC	Lesser sandplover
Aves	Ciconiiformes	Ciconiidae	*Ciconia episcopus*	NT	Asian woollyneck
Aves	Cuculiformes	Cuculidae	*Clamator coromandus*	LC	Chestnut-winged cuckoo
Aves	Accipitriformes	Accipitridae	*Clanga clanga*	VU	Greater spotted eagle
Aves	Passeriformes	Muscicapidae	*Copsychus saularis*	LC	Oriental magpie-robin
Aves	Passeriformes	Muscicapidae	*Cyornis rubeculoides*	LC	Blue-throated blue-flycatcher
Aves	Caprimulgiformes	Apodidae	*Cypsiurus balasiensis*	LC	Asian palm-swift
Aves	Anseriformes	Anatidae	*Dendrocygna javanica*	LC	Lesser whistling-duck
Aves	Passeriformes	Motacillidae	*Dendronanthus indicus*	LC	Forest wagtail
Aves	Passeriformes	Timaliidae	*Dumetia atriceps*	LC	Dark-fronted babbler
Aves	Pelecaniformes	Ardeidae	*Egretta garzetta*	LC	Little egret
Aves	Pelecaniformes	Ardeidae	*Egretta gularis*	LC	Western reef-egret
Aves	Ciconiiformes	Ciconiidae	*Ephippiorhynchus asiaticus*	NT	Black-necked stork
Aves	Passeriformes	Muscicapidae	*Eumyias thalassinus*	LC	Verditer flycatcher
Aves	Suliformes	Fregatidae	*Fregata ariel*	LC	Lesser frigatebird
Aves	Coraciiformes	Alcedinidae	*Halcyon pileata*	VU	Black-capped kingfisher
Aves	Coraciiformes	Alcedinidae	*Halcyon smyrnensis*	LC	White-breasted kingfisher
Aves	Accipitriformes	Accipitridae	*Haliastur indus*	LC	Brahminy kite
Aves	Caprimulgiformes	Hemiprocnidae	*Hemiprocne coronata*	LC	Crested treeswift
Aves	Ciconiiformes	Ciconiidae	*Leptoptilos javanicus*	VU	Lesser adjutant
Aves	Gruiformes	Rallidae	*Lewinia striata*	LC	Slaty-breasted rail
Aves	Coraciiformes	Meropidae	*Merops philippinus*	LC	Blue-tailed bee-eater
Aves	Suliformes	Phalacrocoracidae	*Microcarbo niger*	LC	Little cormorant
Aves	Passeriformes	Muscicapidae	*Muscicapa dauurica*	LC	Asian brown flycatcher
Aves	Strigiformes	Strigidae	*Ninox scutulata*	LC	Brown boobook
Aves	Charadriiformes	Scolopacidae	*Numenius arquata*	NT	Eurasian curlew
Aves	Charadriiformes	Scolopacidae	*Numenius phaeopus*	LC	Whimbrel
Aves	Pelecaniformes	Ardeidae	*Nycticorax nycticorax*	LC	Black-crowned night-heron

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Psittaciformes	Psittacidae	*Palaeornis eupatria*	NT	Alexandrine parakeet
Aves	Accipitriformes	Pandionidae	*Pandion haliaetus*	LC	Osprey
Aves	Coraciiformes	Alcedinidae	*Pelargopsis capensis*	LC	Stork-billed kingfisher
Aves	Suliformes	Phalacrocoracidae	*Phalacrocorax fuscicollis*	LC	Indian cormorant
Aves	Strigiformes	Tytonidae	*Phodilus assimilis*	LC	Sri lanka bay-owl
Aves	Piciformes	Picidae	*Picoides nanus*	LC	Indian pygmy woodpecker
Aves	Pelecaniformes	Threskiornithidae	*Platalea leucorodia*	LC	Eurasian spoonbill
Aves	Charadriiformes	Charadriidae	*Pluvialis fulva*	LC	Pacific golden plover
Aves	Passeriformes	Cisticolidae	*Prinia inornata*	LC	Plain prinia
Aves	Passeriformes	Cisticolidae	*Prinia socialis*	LC	Ashy prinia
Aves	Passeriformes	Pycnonotidae	*Rubigula melanictera*	LC	Black-capped bulbul
Aves	Passeriformes	Sittidae	*Sitta frontalis*	LC	Velvet-fronted nuthatch
Aves	Accipitriformes	Accipitridae	*Spilornis cheela*	LC	Crested serpent-eagle
Aves	Pelecaniformes	Threskiornithidae	*Threskiornis melanocephalus*	NT	Black-headed ibis
Aves	Charadriiformes	Scolopacidae	*Tringa nebularia*	LC	Common greenshank
Aves	Charadriiformes	Scolopacidae	*Xenus cinereus*	LC	Terek sandpiper
Aves	Passeriformes	Zosteropidae	*Zosterops palpebrosus*	LC	Indian white-eye
Chondrichthyes	Rhinopristiformes	Pristidae	*Anoxypristis cuspidata*	EN	Narrow sawfish
Chondrichthyes	Myliobatiformes	Dasyatidae	*Brevitrygon imbricata*	VU	Bengal whipray
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus amblyrhynchoides*	VU	Graceful shark
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus amboinensis*	VU	Pigeye shark
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus melanopterus*	VU	Blacktip reef shark
Chondrichthyes	Orectolobiformes	Hemiscylliidae	*Chiloscyllium arabicum*	NT	Arabian carpetshark
Chondrichthyes	Myliobatiformes	Dasyatidae	*Himantura uarnak*	EN	Coach whipray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Himantura undulata*	EN	Honeycomb whipray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Maculabatis gerrardi*	EN	Whitespotted whipray
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Negaprion acutidens*	EN	Sharptooth lemon shark
Chondrichthyes	Myliobatiformes	Dasyatidae	*Pastinachus ater*	VU	Broad cowtail ray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Pateobatis bleekeri*	EN	Bleeker's whipray
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis clavata*	EN	Dwarf sawfish
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis pristis*	CR	Largetooth sawfish
Chondrichthyes	Myliobatiformes	Dasyatidae	*Taeniura lymma*	LC	Bluespotted lagoon ray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Urogymnus granulatus*	VU	Mangrove whipray
Gastropoda	Sorbeoconcha	Potamididae	*Cerithium coralium*	LC	Coral cerith

Class	Order	Family	Scientific name	RLTS category	Common name
Gastropoda	Littorinimorpha	Littorinidae	*Littoraria undulata*	LC	Na
Gastropoda	Sorbeoconcha	Thiaridae	*Sermyla riqueti*	LC	Na
Holothuroidea	Aspidochirotida	Holothuriidae	*Holothuria impatiens*	DD	Bottleneck sea cucumber
Holothuroidea	Aspidochirotida	Holothuriidae	*Holothuria scabra*	EN	Golden sandfish
Insecta	Odonata	Coenagrionidae	*Ceriagrion cerinorubellum*	LC	Na
Insecta	Odonata	Coenagrionidae	*Paracercion malayanum*	LC	Na
Magnoliopsida	Fabales	Fabaceae	*Albizia lebbeck*	LC	Indian siris
Magnoliopsida	Ericales	Lecythidaceae	*Barringtonia asiatica*	LC	Sea putat
Magnoliopsida	Ericales	Lecythidaceae	*Barringtonia racemosa*	LC	Seaside indian oak; fish killer tree
Magnoliopsida	Boraginales	Cordiaceae	*Cordia subcordata*	LC	Beach cordia
Magnoliopsida	Fabales	Fabaceae	*Dalbergia candenatensis*	LC	Na
Magnoliopsida	Fabales	Fabaceae	*Dalbergia horrida*	NT	Prickly dalbergia
Magnoliopsida	Fabales	Fabaceae	*Dalbergia rostrata*	LC	Hornet creeper
Magnoliopsida	Fabales	Fabaceae	*Dalbergia spinosa*	LC	Na
Magnoliopsida	Malvales	Malvaceae	*Hibiscus tiliaceus*	LC	Coast cottonwood. Sea hibiscus
Magnoliopsida	Malvales	Malvaceae	*Thespesia populnea*	LC	Portia tree
Magnoliopsida	Caryophyllales	Cactaceae	*Rhipsalis baccifera*	LC	Mistletoe cactus
Mammalia	Carnivora	Mustelidae	*Aonyx cinereus*	VU	Asian small-clawed otter
Mammalia	Rodentia	Muridae	*Bandicota bengalensis*	LC	Lesser bandicoot rat
Mammalia	Sirenia	Dugongidae	*Dugong dugon*	VU	Dugong
Mammalia	Rodentia	Sciuridae	*Funambulus palmarum*	LC	Common palm squirrel
Mammalia	Chiroptera	Vespertilionidae	*Hesperoptenus tickelli*	LC	Tickell's bat
Mammalia	Chiroptera	Hipposideridae	*Hipposideros ater*	LC	Dusky leaf-nosed bat
Mammalia	Chiroptera	Hipposideridae	*Hipposideros galeritus*	LC	Cantor's leaf-nosed bat
Mammalia	Chiroptera	Hipposideridae	*Hipposideros lankadiva*	LC	Indian leaf-nosed bat
Mammalia	Chiroptera	Hipposideridae	*Hipposideros speoris*	LC	(Schneidera leaf-nosed bat)
Mammalia	Carnivora	Mustelidae	*Lutra lutra*	NT	Eurasian otter
Mammalia	Carnivora	Mustelidae	*Lutrogale perspicillata*	VU	Smooth-coated otter
Mammalia	Chiroptera	Megadermatidae	*Lyroderma lyra*	LC	Greater false vampire
Mammalia	Chiroptera	Megadermatidae	*Megaderma spasma*	LC	Lesser false vampire
Mammalia	Chiroptera	Vespertilionidae	*Myotis hasseltii*	LC	Lesser large-footed myotis
Mammalia	Cetartiodactyla	Phocoenidae	*Neophocaena phocaenoides*	VU	Indo-pacific finless porpoise
Mammalia	Carnivora	Viverridae	*Paradoxurus hermaphroditus*	LC	Common palm civet
Mammalia	Chiroptera	Vespertilionidae	*Pipistrellus ceylonicus*	LC	Kelaart's pipistrelle
Mammalia	Chiroptera	Vespertilionidae	*Pipistrellus coromandra*	LC	Coromandel pipistrelle
Mammalia	Carnivora	Felidae	*Prionailurus bengalensis*	LC	Mainland

Class	Order	Family	Scientific name	RLTS category	Common name
					leopard cat
Mammalia	Carnivora	Felidae	*Prionailurus viverrinus*	VU	Fishing cat
Mammalia	Rodentia	Muridae	*Rattus rattus*	LC	House rat
Mammalia	Cetartiodactyla	Delphinidae	*Sousa plumbea*	EN	Indian ocean humpback dolphin
Mammalia	Cetartiodactyla	Suidae	*Sus scrofa*	LC	Wild boar
Mammalia	Carnivora	Viverridae	*Viverricula indica*	LC	Small indian civet
Reptilia	Squamata	Acrochordidae	*Acrochordus granulatus*	LC	Wart snake
Reptilia	Squamata	Colubridae	*Ahaetulla nasuta*	LC	Long-nosed tree snake
Reptilia	Squamata	Homalopsidae	*Cerberus rynchops*	LC	South asian bockadam
Reptilia	Squamata	Chamaeleonidae	*Chamaeleo zeylanicus*	LC	Asian chameleon
Reptilia	Squamata	Colubridae	*Chrysopelea ornata*	LC	Ornate flying snake
Reptilia	Squamata	Colubridae	*Coelognathus helenae*	LC	Trinket snake
Reptilia	Squamata	Viperidae	*Echis carinatus*	LC	Saw-scaled viper
Reptilia	Testudines	Cheloniidae	*Eretmochelys imbricata*	CR	Hawksbill turtle
Reptilia	Squamata	Homalopsidae	*Gerarda prevostiana*	LC	Gerard's water snake
Reptilia	Squamata	Gekkonidae	*Hemidactylus depressus*	LC	Sri lanka leaf-toed gecko
Reptilia	Squamata	Gekkonidae	*Hemiphyllodactylus typus*	LC	Indo-pacific slender gecko
Reptilia	Squamata	Elapidae	*Hydrophis cyanocinctus*	LC	Annulated sea snake
Reptilia	Squamata	Elapidae	*Hydrophis gracilis*	LC	Graceful small-headed seasnake
Reptilia	Squamata	Elapidae	*Hydrophis schistosus*	LC	Beaked sea snake
Reptilia	Squamata	Typhlopidae	*Indotyphlops braminus*	LC	Brahminy blindsnake
Reptilia	Squamata	Elapidae	*Laticauda colubrina*	LC	Yellow-lipped sea krait
Reptilia	Squamata	Gekkonidae	*Lepidodactylus lugubris*	LC	Mourning gecko
Reptilia	Squamata	Elapidae	*Ophiophagus hannah*	VU	King cobra
Reptilia	Testudines	Trionychidae	*Pelochelys cantorii*	CR	Asian giant softshell turtle
Reptilia	Squamata	Viperidae	*Trimeresurus gramineus*	LC	Common bamboo viper
Reptilia	Squamata	Varanidae	*Varanus salvator*	LC	Common water monitor

3. National Estimates for subcriterion A1

To estimate the South India, Sri Lanka, and Maldives mangrove ecosystem extent in 1970, we gathered reliable information on the mangrove area for each country within the province around this period (Table b). We then estimated the mangrove area in 1970 for each country, assuming a linear relationship between mangrove extent and time. Finally, we summed up the country estimates to determine the total mangrove area in the South India, Sri Lanka, and Maldives province (Table a). We assumed that the percentage of mangrove extent by country within the province remained constant over time, as the percentages did not change between 1996 and 2020 (GMW v3.0 dataset). However, using mangrove area estimates from different sources can lead to uncertainty (Friess and Webb 2014)[2] and there were no regional statistics or global studies available for this time period. Thus, the estimates for 1970 should be considered only indicative. No reliable mangrove area estimates were available for the Maldives before 1996. As it comprises just 1% of the total area in the 'S India, Sri Lanka, Maldives' province, we assumed no change in Maldivian mangrove forests over the last 50 years for the criterion A1 calculation.

Table a. Estimated mangrove area by country in 1970 and 2020. Estimates for 2020* mangrove area are based on the Global Mangrove Watch Version 3 (GMW v3.0) dataset. The references used to calculate mangrove area for each country in 1970 and 2021** are listed below in Table b.**

	GWM v.3		Based on National stats and Literature		
	Country total 2020*	Within province 2020*	Within province 2020*	Country total 1970**	Within province 1970**
India	4037.76	49.44	36.28		23.8
Maldives	0.97	0.97	0.97	0.97	0.97
Sri Lanka	198.77	198.77	159.81	100.0	100.0
The South India, Sri Lanka, and Maldives		249.2	197.06		124.8

Table b. List of selected studies considered to have reliable information on mangrove area for the period around 1970 in each country of the South India, Sri Lanka, and Maldives province.

Country	Year	Mangrove Area (Ha)	Reference
India	1957	571'808	Mathauda, G.S. (1957). The mangrove of India. In Proceedings of the Mangrove Symposium. p. 66-97. Calcutta.
South India		672	Mathauda, G.S. (1957). The mangrove of India. In Proceedings of the Mangrove Symposium. p. 66-97. Calcutta.
India	1963	689'989	Sidhu, S.S. (1963). Studies on the Mangroves of India: I. East Godavari Region. Indian Forester, 89(5): 337-351
India		2'695	Sidhu, S.S. (1963). Studies on the Mangroves of India: I. East Godavari Region. Indian Forester, 89(5): 337-351
India	1980	506'702	FAO, UNEP. (1981). Tropical Forest Resourcess Assesment Project, Forest Resources of Tropical Asia. FAO, UNEP, 475 pp.
India	1987	404'600	Forest Survey of India (2020) The State of the Forest Report. Forest Survey of India. Ministry of Forests and Environment, Government of India
India	1994	482'700	Forest Survey of India. (2020). The State of the Forest Report 1997. Forest Survey of India. Ministry of Forests and Environment, Government of India.
South India	1987	2300	Forest Survey of India. (2020). The State of the Forest Report 1997. Forest Survey of India. Ministry of Forests and Environment, Government of India
South India	1989	4700	Forest Survey of India. (2020). The State of the Forest Report 1997. Forest Survey of India. Ministry of Forests and Environment, Government of India
South India	1991	4700	Forest Survey of India. (2020). The State of the Forest Report 1997. Forest Survey of India. Ministry of Forests and Environment, Government of India
South India	1993	2100	Forest Survey of India. (2020). The State of the Forest Report 1997. Forest Survey of India. Ministry of Forests and Environment, Government of India
South India	1997	21	Forest Survey of India. (2020). The State of the Forest Report 1997. Forest Survey of India. Ministry of Forests and Environment, Government of India (Area of Tamil Nadu, No Mangrove Forest in Kerala in this year)
South India	2019	54	Forest Survey of India. (2020). The State of the Forest Report 1997. Forest Survey of India. Ministry of Forests and Environment, Government of India (Sum of the Area of Kerala and Tamil Nadu)

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Country	Year	Mangrove Area (Ha)	Reference
Sri Lanka	1969	10'000	Aruchelvam, K. (1969). Mangroves. *The Ceylon Forester* 8 (384): 1-34
Sri Lanka	1980	9600	FAO (2007) The World's mangroves 1980–2005. FAO, Rome, Italy.
Sri Lanka	1986	12'189	Coastal Conservation Department Internal Report No.13, quoted in Natural Resources of Sri Lanka: Conditions and Trends, published by the Natural Resources, Energy and Science Authority of Sri Lanka in 1991
Sri Lanka	1997	18'489	National Aquatic Resources Research. (1997) Sri Lanka Fisheries Year Book, Sri Lanka.
Sri Lanka	2021	15981	In: Arulnayagam, Ahalya, Jong-Seong Khim, and Jinsoon Park. (2021). "Floral and Faunal Diversity in Sri Lankan Mangrove Forests: A Systematic Review" *Sustainability* 13, no. 17: 9487. https://doi.org/10.3390/su13179487
Maldives	1996	97	Bunting, P., Rosenqvist, A., Hilarides, L., Lucas, R. M., Thomas, N., Tadono, T., Worthington, T. A., Spalding, M.D., Murray, N. J., & Rebelo, L.-M. (2022). Global Mangrove Extent Change 1996–2020: Global Mangrove Watch Version 3.0. *Remote Sensing*, *14*(15), 3657. https://doi.org/10.3390/rs14153657