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Mangroves of the Sunda Shelf VU

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Abstract

The 'Mangroves of the Sunda Shelf' is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology in the Sunda Shelf province. It includes intertidal forests and shrublands of the marine regions of the Malacca Straits, Gulf of Thailand, southern Viet Nam and the Sunda Shelf/Java Sea. This province has a tropical climate with protracted rainfall that provides very favourable conditions for mangroves. The rich mangrove biota includes 49 species of true mangrove plants and many mangrove-associated taxa. Five mangrove species are in the IUCN Red List of threatened species.

Mangroves in the Sunda Shelf province had a mapped extent in 2020 of 12,350 km^2, representing 8.4% of the global mangrove resource by area. The main threats to mangroves are conversion for agricultural and aquaculture use, or for coastal infrastructure development. These practices impact on the remaining mangroves through coastal erosion, land subsidence and pollution. Climate change (especially sea-level rise) is an additional and serious threat.

Today the Sunda Shelf mangroves cover ≈ 35% less than our broad estimations for 1970, based on country level studies; however, the rate of area loss slowed to -4.8% from 1996 to 2020 and has decelerated further since 2010. The Sunda Shelf mangrove area is estimated to decrease by 13.7% over the next 50 years. Moreover, we estimate that 3.4% of the mangroves are undergoing degradation, and this could rise to 10% over a 50-year period, based on an analysis of the decay of vegetation indexes. These estimates are very conservative; however, no other data sources were available to measure environmental degradation at the province level. More than 30% of the Sunda Shelf mangrove extent could be submerged by 2070 due to sea-level rise.

Overall, the Sunda Shelf mangrove ecosystem is assessed as **Vulnerable (VU)** under subcriteria A1 and C2.

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Keywords:
Mangroves; IUCN Red List of Ecosystems; ecosystem collapse; threats, Vulnerable.

Ecosystem classification:
MFT1.2 Intertidal forests and shrublands
Assessment's distribution:
The Sunda Shelf province
Summary of the assessment:

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

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

Mangroves of The Sunda Shelf VU

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_26 Mangroves of the Sunda Shelf

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

1 Forest

1.7 Forest – Subtropical/tropical mangrove vegetation above high tide level

12 Marine Intertidal

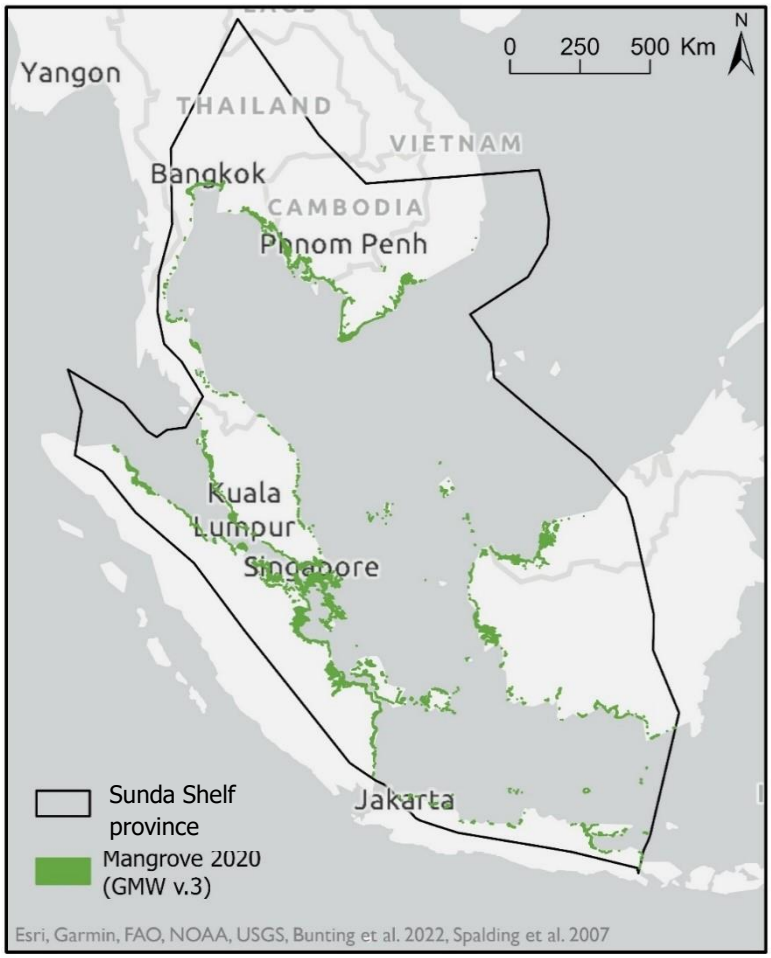
12.7 Mangrove Submerged

Lush mangrove forest typical of the Sunda Shelf province in Koh Kong Province, Cambodia. The vegetation comprises of planted and naturally-regenerating Rhizophora species after mangrove charcoal production was banned (Photo credit: Don Macintosh).

Pioneer mangrove forest dominated by Avicennia marina in West Kalimantan, Indonesia (Photo credit: I Wayan Eka Dharmawan).

A mangrove inlet used as a natural harbour for small fishing boats at Gresik, northern coast of East Java. Traditional coastal communities are still closely associated with mangroves right across the Sunda Shelf province (Photo credit: Frida Sidik).

2. Ecosystem Description



Spatial distribution

The 'Mangroves of the Sunda Shelf' includes intertidal forest and shrublands of the following marine ecoregions: The Gulf of Thailand, Malacca Straits, Southern Viet Nam and Sunda Shelf/Java Sea that extend across six countries and territories of Southeast Asia (Indonesia, Thailand, Cambodia, Malaysia, Singapore and Viet Nam). Mangrove extent in this region was estimated to be 12,350 km^2 in 2020 corresponding to a -4.8% net loss of area since 1996 (from Bunting *et al*. (2022)). The Sunda Shelf mangroves contribute 8.4% of the global mangrove resource by area.

Biotic Components of the Ecosystem (Characteristic native biota)

The biota of 'Mangroves of the Sunda Shelf' is highly diverse compared to other provinces, with 49 true mangrove tree species plus other mangrove-associated plant species (IUCN, 2022). There are five threatened mangrove tree species in the IUCN Red List of Threatened Species (RLTS) database (IUCN, 2022): *Avicennia rumphiana* (Vulnerable, VU), *Bruguiera hainesii* (Critically Endangered, CR), *Heritiera fomes* (Endangered, EN), *Heritiera globosa* (EN) and *Sonneratia griffithii* (CR).

The mangrove fauna in the Sunda Shelf province is particularly rich and productive, with many species of crabs, molluscs, insects, and other invertebrates reported (e.g., Berry, 1972; Murphy, 1990). Up to 60 crabs per square metre have been counted on mangrove soils (Macintosh, 1984). The mangrove avian and fish faunas

are also highly diverse; for example, more than 100 fish species and 150 bird species have been recorded in the Matang mangroves in Perak, Peninsular Malaysia (Abdullah, 2009).

There are at least 108 animal species in the taxa Actinopterygii, Aves, Chondrichthyes, Gastropoda, Insecta, Liliopsidae, Magnoliopsidae, Mammalia and Reptilia that have been associated with mangrove habitats in the IUCN RLTS database (IUCN, 2022) and have natural history collection records or observations within the distribution of this unit (GBIF, 2021). There are 16 threatened animal species, including the Critically Endangered (CR) Indochinese leopard (*Panthera pardus* ssp. *delacouri*); birds: e.g., silvery pigeon (*Columba argentina*, CR) and milky stork (*Mycteria cinerea*, Endangered, EN); and fishes: e.g., large-tooth sawfish (*Pristis pristis*, CR) and Bleeker's stingray (*Pateobatis bleekeri*, EN).

Abiotic components of the ecosystem

Regional mangrove distributions are influenced by interactions among landscape position, rainfall, hydrology, sea-level, sediment dynamics, shore subsidence and storm-driven processes. As in other provinces, rainfall/freshwater and sediment supply from rivers and tidal currents promote mangrove establishment and persistence, while waves and strong tidal currents destabilise and erode mangrove substrata, thereby mediating local-scale dynamics in ecosystem distributions. High rainfall reduces salinity stress and increases nutrient loading from adjacent catchments, while tidal flushing also regulates salinity.

Many coastal areas of the Sunda Shelf province provide highly favourable physical conditions for mangroves. The climate is tropical and mainly equatorial with intense and protracted rainfall. Moreover, the Sunda Shelf is a large, shallow and enclosed marine area bordered by coastlines sheltered from oceanic forces by the landmasses of Indonesia and Malaysia, while the Gulf of Thailand coastline is also very sheltered. Within sheltered deltas and estuaries, the sediments consist mainly of fine-grained silt and clay particles; elsewhere the sediment composition includes various amounts of sand to form sandy mud to muddy sand substrata (e.g., Sasekumar, 1994). Average soil and water salinity conditions are moderate, being typically around 30 ppt NaCl, with significantly lower salinities that are highly favourable for mangrove tree growth prevailing during wet season months.

The Sunda Shelf province includes large deltas (Chao Paya in Thailand, Mekong Delta in Viet Nam) and major river estuaries (e.g., Perak and Selangor rivers in Malaysia, Siak River in Sumatra, Dong Nai River in Viet Nam). Large quantities of freshwater and alluvial sediments are brought to the coast by these riverine systems, where the nutrient-rich alluvium settles to form mud banks and mudflats providing an ideal substratum for mangroves to colonise and grow on. Based on the typology of Worthington *et al*. (2020), the mangroves in the Sunda Shelf province can be classified as mainly deltaic and estuarine, with some open coast fringing formations.

3. Ecosystem Threats and Vulnerabilities

Main threatening process and pathways to degradation

The Sunda Shelf mangrove ecosystem faces multiple threats and there has been a significant loss of mangrove habitat in all the countries within this province due to past conversion for agriculture (e.g., oil palm) or aquaculture (especially shrimp farming); and now increasingly for coastal infrastructure development. Illegal

mangrove forest logging for wood/charcoal or land clearance continues to be a major issue, especially in Indonesia. Coastal shrimp farming, and agricultural irrigation systems that reduce coastal sediment deposition, can also cause soil erosion, thereby threatening adjacent mangroves indirectly. Similarly, coastal infrastructure (ports, harbours, seawalls or roads) can also cause erosion along mangrove-fringed coastlines by disrupting sediment-bearing currents. Mining in or near mangroves for tin or sand can also degrade mangroves either directly, or indirectly by causing erosion.

Multiple impacts in the form of coastal erosion, land subsidence, flooding and pollution (e.g., from shrimp farms) threaten mangroves in some locations of the Sunda Shelf province, such as the inner Gulf of Thailand and northern coast of central Java (Naohiro *et al.*, 2012; Hakim *et al*., 2021). Wastewater and plastic pollution are becoming serious threats near coastal industrial and urban centres. The accumulation of plastic waste in mangrove forests is a global threat that is particularly acute in this province because the countries concerned are major producers and consumers of plastic products (Marks *et al.*, 2020). Oil spills are a high risk to mangroves along the Malacca Straits due to the large number of cargo vessels that use this major waterway.

Climate change is a more recent and growing threat to mangrove ecosystems, especially their exposure to more frequent and severe storms and sea-level rise. Although the Sunda Shelf province does not usually experience cyclones (they have occurred rarely in southern Viet Nam and Thailand), tropical storms causing storm surges and flooding are quite common and can damage mangroves. Sea-level rise coupled with coastal squeeze is threatening mangroves in many areas of the province, particularly along the northern coast of Java, the inner Gulf of Thailand and the Mekong Delta, which have extremely low-lying topographies. However, compared to other coastal ecosystems, mangroves are often less vulnerable to sea-level rise provided sediment flows are sufficient for mangrove development to keep pace with sea-level rise (Schuerch *et al*., 2018).

Integrated mangrove aquaculture ("silvofishery"), a traditional and largely sustainable economic use of mangroves in the Sunda Shelf province, as here in Central Java (Photo credit: Frida Sidik).

Mangroves converted for agriculture (oil-palm plantations) and aquaculture (shrimp farms) in Selangor State, Peninsular Malaysia; m = mangroves
(Photo credit: Gianluca Polgar).

Mangrove converted to housing and shrimp farms leading to coastal erosion and flooding exacerbated by sea-level rise in Demak Regency, Central Java, Indonesia
(Photo credit: Don Macintosh).

Large-scale coastal land reclamation and mangrove conversion for urban and industrial development near Jakarta, northwest coast of Java, Indonesia (Photo credit: Frida Sidik).

Illegal mangrove forest logging for wood/charcoal and land conversion (to aquaculture ponds) in Porong, East Java, Indonesia (Photo credit: Frida Sidik).

An abandoned tin mining site in mangrove forest in Belitung Island, where the local communities have started to rehabilitate the area to convert it back to mangroves (Photo credit: Frida Sidik).

Definition

Mangroves are highly dynamic plant communities with species distributions adjusting to local changes in tidal regimes and inundation, salinity gradients or sedimentation processes. Changes that disrupt these dynamics can impact on key mangrove ecological functions. Thus, ecosystem collapse may occur under any of the following: a) changes in climatic conditions that restrict recruitment and survival of diagnostic true mangroves; b) changes in river and other freshwater inputs and/or waves and tidal currents that destabilise and erode sediments/soils and disrupt recruitment and growth; c) changes in salinity, or pollution, leading to stress on mangroves. Ecosystem collapse is considered to occur when the tree cover of diagnostic species of true mangroves declines to zero (100% loss).

A large area of dead and dying mangrove forest resulting from coastal erosion and climate change in Koh Kong Province, Cambodia (Photo credit: Don Macintosh).

Mortality of mangrove plants and animals can be caused by habitat loss due to coastal land conversion or erosion, osmotic stress (high salinity), chemical toxicity from pollutants, or physical smothering by excess amounts of sediments released from erosion sites and shrimp farms, or by oil spills (Polgar and Jafar, 2018). The direct and indirect impacts from conversion of mangroves to other forms of land use, plus climate change in the form of sea-level rise, are the principal causes of mangrove ecosystem collapse in the Sunda Shelf province. Coastal erosion caused by mangrove conversion is particularly serious in this province.

Threat Classification

IUCN Threat Classification (version 3.3, IUCN 2022) relevant to mangroves of the Sunda Shelf province:

1 Residential & Commercial Development
- 1.1 Housing & Urban Areas
- 1.2 Commercial & Industrial Areas
- 1.3 Tourism & Recreation Areas

2 Agriculture & Aquaculture
- 2.4 Marine & Freshwater aquaculture
  - 2.4.1 Subsistence/Artisanal Aquaculture
  - 2.4.2 Industrial Aquaculture

4 Transportation & Service Corridors
- 4.1 Roads & Railroads

5 Biological Resource Use
- 5.1 Hunting & Collecting Terrestrial Animals
- 5.3 Logging & Wood Harvesting
- 5.4 Fishing & Harvesting Aquatic Resources

7 Natural System modifications
- 7.2 Dams & Water Management/Use

8 Invasive & Other Problematic Species, Genes & Diseases
- 8.1 Invasive Non-Native/Alien Species/Diseases

9 Pollution
- 9.1 Domestic & Urban Wastewater
  - 9.1.1 Sewage
  - 9.1.2 Run-off
- 9.2 Industrial & Military Effluents
  - 9.2.1 Oil Spills
- 9.3 Agricultural & Forestry Effluents
  - 9.3.1 Nutrient Loads
  - 9.3.2 Soil Erosion, Sedimentation
- 9.4 Garbage & Solid Waste

10 Geological events
- 10.2 Earthquakes/Tsunamis

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. Accordingly, we compiled reliable published sources (see appendix 3) that contain information on mangrove area estimates close to 1970 (both before and after) for each country within the province. 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 and the estimated figures for 1970 should be considered only indicative (see appendix 3 for further details of the methods and limitations).

In contrast, to estimate the Sunda Shelf mangrove area from 1996 to 2020, we used the most recent version of Global Mangrove Watch Version 3 (GMW v3.0) spatial dataset. The 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).

The Sunda Shelf	2020*	1970*	Net area Change (Km^2)	% Net Area Change	Rate of change (%/year)
	12,350	18,916	-6,566.20	-34.7	-0.69%

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

Results from the analysis of subcriterion A1 show that the Sunda Shelf province has lost approximately 34.7% of its mangrove area over the past 50 years (1970-2020). Indeed, five of the six countries in this province have lost more than 30% of their mangrove area (appendix 3). The Indonesian coast, which represents 67% of the Sunda Shelf province, has lost 37% of its mangrove area, while the range in area loss by country was 84% (Singapore) to 23% (Thailand). However, at the province level the GMW v3.0 dataset indicates that the rate of loss has declined since 2010.

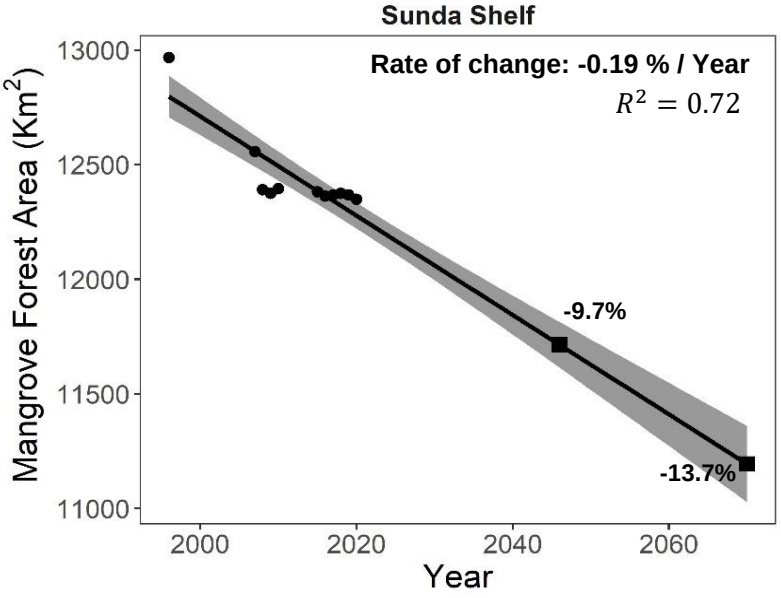


Figure 1. Sunda Shelf province mangrove extent decline projected to 2070. Circles represent the province mangrove area times series between 1996 and 2020. Area estimates are based on GMW v3.0 dataset and equations in Bunting *et al.* (2022). The solid line and shaded area are the linear regression and 95% confidence interval. Squares show Sunda Shelf province predicted mangrove area for 2046 and 2070.

Given that the loss of 34.7% in mangrove area over the last 50 years is higher than 30%, but less than the 50% risk threshold, the Sunda Shelf mangrove ecosystem is assessed as **Vulnerable (VU)** under subcriterion

A1.

Subcriterion A2 assesses the change in ecosystem extent in any 50-year period, including from the present to the future: The Sunda Shelf province mangroves show a net area loss of ≈ 5% (1996-2020) based on Global Mangrove Watch time series (Bunting *et al.*, 2022). This value reflects the offset between areas gained (+0.12%/year) and lost (-0.32%/year). The largest decline in mangrove area occurred between 1996 and 2010; but since then there has been a deceleration in net area loss. Applying a linear regression to the area estimations between 1996 and 2020 we obtained a rate of change of -0.19 %/year (figure 1). Assuming this trend continues, it is predicted that the extent of mangroves in the Sunda Shelf province will decrease by -9.7% from 1996 to 2046; by -13.7% from 1996 to 2070; but only by -9.4% from 2020-2070. Given that these predicted changes in mangrove extent are much less than the 30% risk threshold, the ecosystem is assessed as **Least Concern (LC)** under subcriteria A2a and A2b.

Subcriterion A3 measures change 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 Sunda Shelf mangrove ecosystem is classified as **Data Deficient (DD)** for this subcriterion.

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

Criterion B: Restricted Geographic Distribution

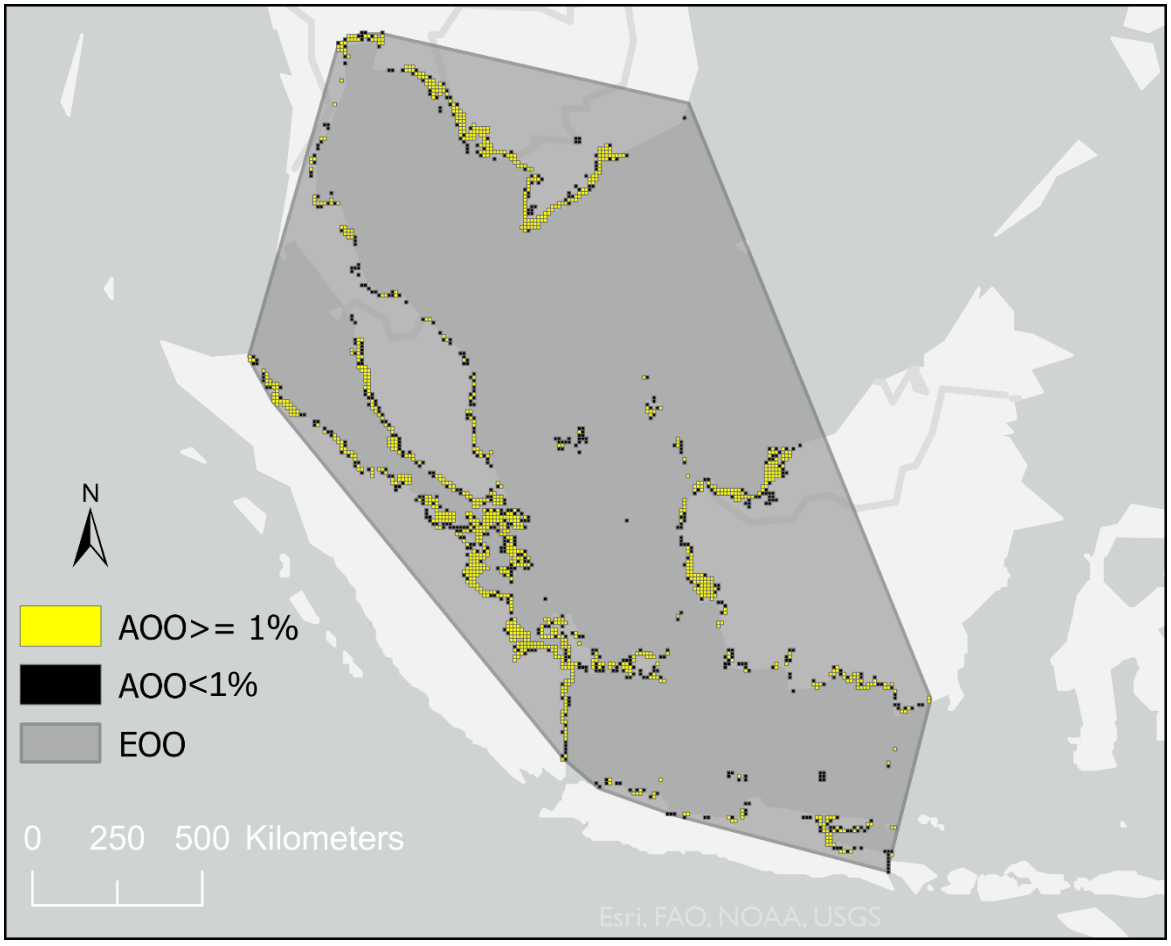


Figure 2. Sunda Shelf mangrove in 2020: Extent Of Occurrence (EOO) and Area Of Occupancy (AOO). Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022). The yellow 10 x 10 km grids are more than 1% covered by the ecosystem, and the black grids <1%.

Criterion B measures the risk of collapse associated with restricted geographic distribution, based on standard metrics (Extent of Occurrence EOO, Area of Occupancy AOO, and Threat-defined locations).

Province	Extent of Occurrence EOO (Km^2)	Area of Occupancy (AOO)	Criterion B
Sunda Shelf	2,892,610	1,095	LC

For 2020 the Sunda Shelf province AOO and EOO were measured as 1,095 grid cells 10 x 10 km and 2,892,610 km2 respectively (figure 2), based on the GMW v3.0 dataset. 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 Sunda Shelf mangrove ecosystem is assessed as **Least Concern (LC)** under criterion B.

Criterion C: Environmental Degradation

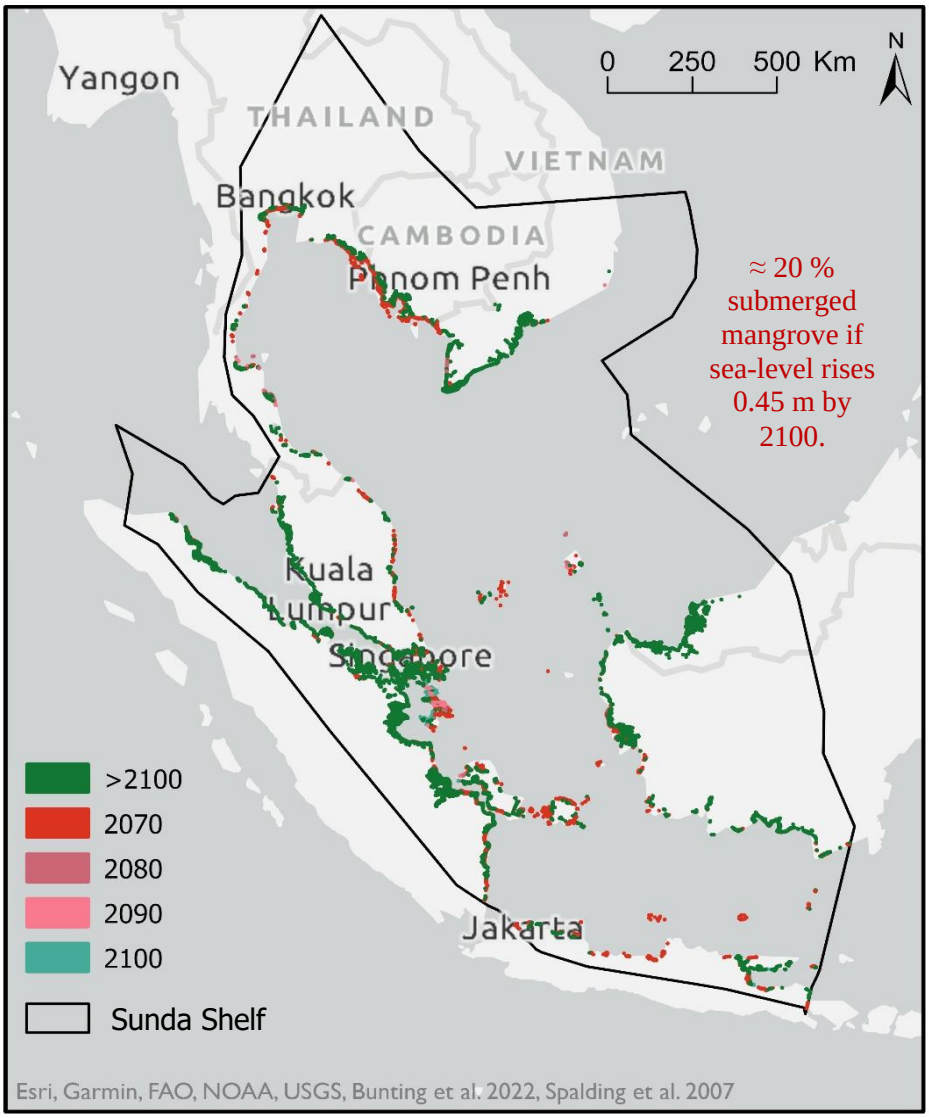


Figure 3. Sunda Shelf mangrove forest predicted decade of submerge under IPCC RCP 6 scenario (0.45 m Global SLR by 2100), based on the model of Lovelock *et al.* (2015). Mangrove area based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022).

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 on mangrove degradation for the entire province to evaluate this subcriterion, and therefore the Sunda Shelf 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: A model on the impact of sea-level rise (SLR) accounting for sediment supply and its effects on coastal submersion (Lovelock *et al*., 2015) was applied to the Sunda Shelf mangrove area province (2020 spatial layer, GMW v3.0) to estimate the percentage of mangrove area that would be submerged over the next 50 years. The model assumes homogenous SLR across the province and does not account for mangrove landward migration.

Using this model and considering a plausible mid-high SLR scenario (IPCC RCP6, 0.45 m SLR by 2100) ≈20% of the Sunda Shelf mangrove forest would be submerged by 2070 (figure 3). However, under a more extreme SLR scenario, 1.4 m SLR by 2100 (figure 4 in Lovelock *et al.* (2015)), the area projected to be submerged by 2070 exceeds the 30% extent of decline threshold. Considering the relative severity of this impact to be >80% because no mangrove recruitment can occur in a submerged system, and using the precautionary principle, the Sunda Shelf mangrove ecosystem is assessed as **Vulnerable (VU)** under subcriterion C2.

Subcriterion C3 measures change in abiotic variables since 1750. There is a lack of reliable historic data covering the entire province, and therefore the Sunda Shelf province is classified as **Data Deficient (DD)** for this subcriterion.

Overall, the Sunda Shelf mangrove ecosystem is assessed as **Vulnerable (VU)** 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 Sunda Shelf province. This map is based on degradation metrics calculated from vegetation indices (NDVI, EVI, SAVI, NDMI) using Landsat times series between ≈2000 and 2017. These indices represent vegetation greenness and moisture condition.

Mangrove degradation was calculated at the 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 *et al.*, 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 (~2000-2017), 3.4% of the Sunda Shelf mangrove area has degraded, resulting in an average annual rate of degradation of 0.2%. Assuming that this

trend remains constant, 10% of the Sunda Shelf's mangrove area will be classified as degraded over the next 50-year period (2020-2070). Less than 50% of the ecosystem will meet the category thresholds for criterion D2. The ecosystem is therefore 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 Sunda Shelf mangrove ecosystem remains of **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 **VU**	**A2** Future or Any 50y period LC	**A3** Historical (1750) **DD**
B. Restricted Geo. Distribution	**B1** Extent of Occurrence **LC**	**B2** Area of Occupancy **LC**	**B3** # Threat-defined Locations < 5? **No**
C. Environmental Degradation	**C1** Past 50 years (1970) **DD**	**C2** Future or Any 50y period **VU**	**C3** Historical (1750) **DD**
D. Disruption of biotic processes	**D1** Past 50 years (1970) **DD**	**D2** Future or Any 50y period **LC**	**D3** Historical (1750) **DD**
E. Quantitative Risk analysis		NE	
OVERALL RISK CATEGORY		**VU**	

DD = Data Deficient; LC = Least Concern; NE = Not Evaluated, VU= Vulnerable.

Overall, the status of the Sunda Shelf mangrove ecosystem is assessed as **Vulnerable (VU).**

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7. 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
Liliopsida	Arecales	Arecaceae	*Nypa fruticans*	LC
Liliopsida	Arecales	Arecaceae	*Phoenix paludosa*	NT
Magnoliopsida	Ericales	Primulaceae	*Aegiceras corniculatum*	LC
Magnoliopsida	Ericales	Primulaceae	*Aegiceras floridum*	NT
Magnoliopsida	Fabales	Fabaceae	*Cynometra iripa*	LC
Magnoliopsida	Gentianales	Rubiaceae	*Scyphiphora hydrophylacea*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Acanthus ebracteatus*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Acanthus ilicifolius*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Acanthus volubilis*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia alba*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia marina*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia officinalis*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia rumphiana*	VU
Magnoliopsida	Lamiales	Bignoniaceae	*Dolichandrone spathacea*	LC
Magnoliopsida	Malpighiales	Euphorbiaceae	*Excoecaria agallocha*	LC
Magnoliopsida	Malpighiales	Euphorbiaceae	*Excoecaria indica*	DD
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera cylindrica*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera exaristata*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera gymnorhiza*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera hainesii*	CR
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera parviflora*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera sexangula*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Ceriops decandra*	NT
Magnoliopsida	Malpighiales	Rhizophoraceae	*Ceriops tagal*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Ceriops zippeliana*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Kandelia candel*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Kandelia obovata*	LC
Magnoliopsida	Malvales	Malvaceae	*Brownlowia argentata*	DD
Magnoliopsida	Malvales	Malvaceae	*Brownlowia tersa*	NT
Magnoliopsida	Malvales	Malvaceae	*Camptostemon schultzii*	LC
Magnoliopsida	Malvales	Malvaceae	*Heritiera fomes*	EN
Magnoliopsida	Malvales	Malvaceae	*Heritiera globosa*	EN
Magnoliopsida	Malvales	Malvaceae	*Heritiera littoralis*	LC
Magnoliopsida	Myrtales	Combretaceae	*Lumnitzera littorea*	LC
Magnoliopsida	Myrtales	Combretaceae	*Lumnitzera racemosa*	LC
Magnoliopsida	Myrtales	Lythraceae	*Pemphis acidula*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia alba*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia caseolaris*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia griffithii*	CR
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia ovata*	NT
Magnoliopsida	Myrtales	Myrtaceae	*Osbornia octodonta*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora stylosa*	LC

Class	Order	Family	Scientific name	RLTS category
Magnoliopsida	Sapindales	Meliaceae	*Aglaia cucullata*	DD
Magnoliopsida	Sapindales	Meliaceae	*Xylocarpus granatum*	LC
Magnoliopsida	Sapindales	Meliaceae	*Xylocarpus moluccensis*	LC
Polypodiopsida	Polypodiales	Pteridaceae	*Acrostichum aureum*	LC
Polypodiopsida	Polypodiales	Pteridaceae	*Acrostichum speciosum*	LC

2. List of Associated Species

List of taxa that are associated with mangrove habitats in the Red List of Threatened Species 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". We further filtered species with spatial point records in GBIF (some species are excluded due to mismatch in taxonomic names or lack of georeferenced records). 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
Liliopsida	Asparagales	Orchidaceae	*Paphiopedilum bullenianum*	EN	Bullen's paphiopedilum
Magnoliopsida	Fabales	Fabaceae	*Cynometra ramiflora*	LC	
Actinopterygii	Albuliformes	Albulidae	*Albula vulpes*	NT	Bonefish
Actinopterygii	Anguilliformes	Muraenidae	*Gymnothorax funebris*	LC	Green moray
Actinopterygii	Anguilliformes	Muraenidae	*Uropterygius concolor*	LC	Brown moray eel
Actinopterygii	Atheriniformes	Phallostethidae	*Phallostethus lehi*	DD	
Actinopterygii	Atheriniformes	Phallostethidae	*Phenacostethus posthon*	LC	
Actinopterygii	Beloniformes	Zenarchopteridae	*Zenarchopterus ectuntio*	LC	
Actinopterygii	Beloniformes	Zenarchopteridae	*Zenarchopterus gilli*	LC	Shortnose river garfish
Actinopterygii	Clupeiformes	Clupeidae	*Sardinella melanura*	LC	Blacktip sardinella
Actinopterygii	Clupeiformes	Engraulidae	*Encrasicholina punctifer*	LC	Buccaneer anchovy
Actinopterygii	Clupeiformes	Engraulidae	*Setipinna breviceps*	LC	[Shorthead hairfin anchovy]
Actinopterygii	Clupeiformes	Engraulidae	*Stolephorus andhraensis*	LC	Andhra anchovy
Actinopterygii	Clupeiformes	Engraulidae	*Thryssa kammalensis*	DD	[Kammal thrysa]
Actinopterygii	Cypriniformes	Cobitidae	*Pangio kuhlii*	LC	[Coolie loach]
Actinopterygii	Elopiformes	Elopidae	*Elops hawaiensis*	DD	Giant herring
Actinopterygii	Gobiiformes	Eleotridae	*Butis amboinensis*	LC	Ambon gudgeon
Actinopterygii	Gobiiformes	Eleotridae	*Butis gymnopomus*	LC	Striped crazy fish
Actinopterygii	Gobiiformes	Gobiidae	*Amblygobius stethophthalmus*	LC	Freckled goby
Actinopterygii	Gobiiformes	Gobiidae	*Cryptocentrus leptocephalus*	LC	Pink-speckled Shrimpgoby
Actinopterygii	Gobiiformes	Gobiidae	*Exyrias puntang*	LC	Puntang goby

Class	Order	Family	Scientific Name	RLTS category	Common name
Actinopterygii	Gobiiformes	Gobiidae	*Glossogobius circumspectus*	LC	Circumspect goby
Actinopterygii	Gobiiformes	Gobiidae	*Gnatholepis ophthalmotaenia*	LC	
Actinopterygii	Gobiiformes	Gobiidae	*Gobiopterus brachypterus*	DD	
Actinopterygii	Gobiiformes	Gobiidae	*Mangarinus waterousi*	DD	Uchiwahaze
Actinopterygii	Gobiiformes	Gobiidae	*Parachaeturichthys polynema*	LC	Lancet-tail Goby
Actinopterygii	Gobiiformes	Gobiidae	*Paratrypauchen microcephalus*	LC	Comb goby
Actinopterygii	Gobiiformes	Gobiidae	*Periophthalmodon septemradiatus*	LC	
Actinopterygii	Gobiiformes	Gobiidae	*Pseudogobius poicilosoma*	LC	Northern fatnose goby
Actinopterygii	Gobiiformes	Gobiidae	*Redigobius balteatus*	LC	Girdled goby
Actinopterygii	Gobiiformes	Gobiidae	*Taenioides buchanani*	DD	Burmese gobyeel
Actinopterygii	Gobiiformes	Gobiidae	*Taenioides cirratus*	DD	Whiskered eel goby
Actinopterygii	Gobiiformes	Gobiidae	*Trypauchenopsis intermedia*	LC	Bearded eel goby
Actinopterygii	Gobiiformes	Gobiidae	*Mahidolia mystacina*	LC	Flagfin prawn goby
Actinopterygii	Perciformes	Ambassidae	*Ambassis macracanthus*	DD	Estuarine glass perchlet
Actinopterygii	Perciformes	Apogonidae	*Yarica hyalosoma*	LC	Mangrove cardinalfish
Actinopterygii	Perciformes	Blenniidae	*Omobranchus ferox*	LC	Gossamer blenny
Actinopterygii	Perciformes	Blenniidae	*Omox biporos*	LC	Omox blenny
Actinopterygii	Perciformes	Carangidae	*Atule mate*	LC	Yellowtail scad
Actinopterygii	Gobiiformes	Eleotridae	*Oxyeleotris urophthalmus*	DD	
Actinopterygii	Perciformes	Ephippidae	*Platax orbicularis*	LC	Orbiculate batfish
Actinopterygii	Perciformes	Gerreidae	*Gerres erythrourus*	LC	Deep-bodied Mojarra
Actinopterygii	Perciformes	Haemulidae	*Diagramma labiosum*	LC	Painted sweetlips
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus gibbosus*	LC	Brown sweetlips
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus pictus*	LC	Trout sweetlips
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 fulviflamma*	LC	Dory snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulvus*	LC	Blacktail snapper
Actinopterygii	Perciformes	Microdesmidae	*Parioglossus formosus*	LC	[Beautiful hover goby]
Actinopterygii	Perciformes	Sciaenidae	*Aspericorvina jubata*	LC	Prickly croaker
Actinopterygii	Perciformes	Sciaenidae	*Johnius australis*	LC	Bottlenose jewfish
Actinopterygii	Perciformes	Sciaenidae	*Johnius carouna*	LC	Caroun croaker

Class	Order	Family	Scientific Name	RLTS category	Common name
Actinopterygii	Perciformes	Sciaenidae	*Johnius latifrons*	DD	[Broad-head croaker]
Actinopterygii	Perciformes	Sciaenidae	*Panna microdon*	LC	Panna croaker
Actinopterygii	Perciformes	Siganidae	*Siganus guttatus*	LC	Golden rabbitfish
Actinopterygii	Perciformes	Siganidae	*Siganus lineatus*	LC	Lined rabbitfish
Actinopterygii	Perciformes	Siganidae	*Siganus vermiculatus*	LC	Vermiculated spinefoot
Actinopterygii	Perciformes	Toxotidae	*Toxotes jaculatrix*	LC	Banded archerfish
Actinopterygii	Scorpaeniformes	Platycephalidae	*Cymbacephalus beauforti*	LC	Crocodile fish
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron reticularis*	LC	Reticulated pufferfish
Aves	Ciconiiformes	Ciconiidae	*Leptoptilos javanicus*	VU	Lesser adjutant
Aves	Ciconiiformes	Ciconiidae	*Mycteria cinerea*	EN	Milky stork
Aves	Columbiformes	Columbidae	*Columba argentina*	CR	Silvery pigeon
Aves	Columbiformes	Columbidae	*Ducula badia*	LC	Mountain imperial-pigeon
Aves	Coraciiformes	Alcedinidae	*Halcyon coromanda*	LC	Ruddy kingfisher
Aves	Coraciiformes	Alcedinidae	*Halcyon pileata*	LC	Black-capped kingfisher
Aves	Coraciiformes	Alcedinidae	*Pelargopsis amauroptera*	NT	Brown-winged kingfisher
Aves	Coraciiformes	Alcedinidae	*Todiramphus chloris*	LC	Collared kingfisher
Aves	Cuculiformes	Cuculidae	*Centropus nigrorufus*	VU	Javan coucal
Aves	Cuculiformes	Cuculidae	*Phaenicophaeus sumatranus*	NT	Chestnut-bellied malkoha
Aves	Passeriformes	Acanthizidae	*Gerygone sulphurea*	LC	Golden-bellied gerygone
Aves	Passeriformes	Aegithinidae	*Aegithina tiphia*	LC	Common iora
Aves	Passeriformes	Cisticolidae	*Orthotomus ruficeps*	LC	Ashy tailorbird
Aves	Passeriformes	Cisticolidae	*Prinia familiaris*	NT	Bar-winged prinia
Aves	Passeriformes	Meliphagidae	*Lichmera indistincta*	LC	Brown honeyeater
Aves	Passeriformes	Muscicapidae	*Cyornis rufigastra*	LC	Mangrove blue-flycatcher
Aves	Passeriformes	Pachycephalidae	*Pachycephala cinerea*	LC	Mangrove whistler
Aves	Passeriformes	Pachycephalidae	*Pachycephala phaionota*	LC	Island whistler
Aves	Passeriformes	Pittidae	*Pitta megarhyncha*	NT	Mangrove pitta
Aves	Passeriformes	Sturnidae	*Aplonis mysolensis*	LC	Moluccan starling
Aves	Passeriformes	Zosteropidae	*Zosterops flavus*	EN	Javan white-eye
Aves	Piciformes	Picidae	*Picus viridanus*	LC	Streak-breasted woodpecker
Aves	Suliformes	Anhingidae	*Anhinga melanogaster*	NT	Oriental darter
Chondrichthyes	Myliobatiformes	Dasyatidae	*Himantura leoparda*	VU	Leopard whipray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Maculabatis macrura*	EN	Sharpnose whipray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Pastinachus gracilicaudus*	EN	Narrow cowtail ray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Pateobatis bleekeri*	EN	Bleeker's whipray
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis pectinata*	CR	Smalltooth sawfish
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis pristis*	CR	Largetooth sawfish
Gastropoda	Cycloneritida	Neritidae	*Neritodryas subsulcata*	DD	Weakly cut nerite

Class	Order	Family	Scientific Name	RLTS category	Common name
Gastropoda	Ellobiida	Ellobiidae	*Ellobium aurisjudae*	LC	Judas ear cassidula
Gastropoda	Littorinimorpha	Littorinidae	*Littoraria undulata*	LC	[Robust shell]
Gastropoda	Neogastropoda	Conidae	*Conus frigidus*	LC	Frigid cone
Gastropoda	Neogastropoda	Conidae	*Conus furvus*	LC	[Dark cone]
Gastropoda	Neogastropoda	Conidae	*Conus insculptus*	LC	[Engraved cone]
Gastropoda	Neogastropoda	Conidae	*Conus varius*	LC	[Freckled cone]
Insecta	Odonata	Libellulidae	*Pornothemis starrei*	NT	[Mangrove marshal]
Mammalia	Carnivora	Felidae	*Panthera pardus ssp. delacouri*	CR	Indochinese leopard
Mammalia	Cetartiodactyla	Phocoenidae	*Neophocaena phocaenoides*	VU	Indo-Pacific finless porpoise
Mammalia	Primates	Tarsiidae	*Tarsius tarsier*	VU	Spectral tarsier
Reptilia	Squamata	Elapidae	*Bungarus fasciatus*	LC	Banded krait
Reptilia	Squamata	Pythonidae	*Python bivittatus*	VU	Burmese python
Reptilia	Squamata	Viperidae	*Trimeresurus purpureomaculatus*	LC	Mangrove pit viper

3. National Estimates for Subcriterion A1

To estimate the Sunda Shelf 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 Sunda Shelf province. 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). Using mangrove area estimates from different sources can lead to uncertainty (Friess and Webb, 2014); however, there were no regional statistics or global studies available for this time period. Thus, the estimates for 1970 should be considered only indicative.

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 are listed below in Table b.

Year	Country Total 2020*	Within Province 2020*	Country Total 1970**	Within Province 1970**
Cambodia	647	627	958	958
Indonesia	7,546	7,174	46,608	11,321
Malaysia	2,289	2,210	7,357	3,100
Singapore	8	7	46	46
Thailand	842	790	3,267	1,021
Viet Nam	1,636	1,541	2,99	2,470
The Sunda Shelf		**12,350**		**18,916**

Table b. List of selected studies considered to have reliable information on mangrove area for the period around 1970 in each country of the Sunda Shelf province.

Country	Year	Mangrove Area (Ha)	Reference
Cambodia	1950	100,700	BIMS (1997). Biodiversity Information Management System. Indo-Malayan Realm Study Final report.
Cambodia	1975	94,600	The Mekong Secretariat, UNDP, FAO (1994). Cambodia Land Cover Atlas. Cambodia Land Cover Atlas. 1985/87 - 1992/1993. Remote sensing & Mapping unit, Mekong Secretariat, UNDP, FAO, Cambodia. 124 pp.
Indonesia	1982	4,251,011	FAO (2002). FAO's database on mangrove area estimates, by M.L. Wilkie,M.L., Fortuna, S., & Souksavat, O. Forest Resources Assessment Working Paper No. 62. Rome.
Malaysia	1975	688,634	FAO (1982). *Management and utilization of mangroves in Asia and the Pacific.* FAO environment paper 3. 160 pp.
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