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Mangroves of The Bay of Bengal LC

Donald J. Macintosh[1,2], Ena L. Suárez[3], Toe Aung[4], Daniel A. Friess[5], Calvin K. F. Lee[6], Mohammed Hossain[7], Maeve Nightingale[8] & Marcos Valderrábano[3]

[1] School of Environment, Resources and Development, Asian Institute of Technology, Pathum Thani 12120, Thailand.
[2] Red List of Ecosystems Adviser, International Union for Conservation of Nature IUCN HQ, Gland 1196, Switzerland.
[3] International Union for Conservation of Nature IUCN HQ, Gland 1196, Switzerland.
[4] Climate Change and Blue Carbon Program, Worldview International Foundation, Yangon, Myanmar.
[5] Department of Earth and Environmental Sciences, Tulane University, New Orleans, Louisiana 70118, USA.
[6] School of Biological Sciences, The University of Hong Kong, Hong Kong, China.
[7] Botanical Garden and Eco-Park, Chattogram, Bangladesh Forest Department, Chattogram 4000, Bangladesh.
[8] International Union for Conservation of Nature IUCN Asia Regional Office, Bangkok 10110, Thailand.

Abstract

Mangroves of the Bay of Bengal is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology) spanning parts of South and Southeast Asia. It includes coastal areas of eastern India, Bangladesh, and northern and central Myanmar, and contains one of the largest single mangrove ecosystems in the world: the Sundarbans.

Mangroves dominate along the extensive coastal waterways of the Ganges-Brahmaputra and Ayeyarwady deltas in India-Bangladesh and Myanmar, respectively. They occur on mainly coastal alluvial sediments deposited by these and other river systems. Their mapped extent in 2020 was 10,250 km^2, representing 7% of the global mangrove area.

The Bay of Bengal province mangroves are threatened by high population pressure and intense natural resources use, including mangrove-associated fisheries and conversion to agriculture or aquaculture. Mangrove degradation and conversion have caused serious coastal erosion. Destructive cyclones exacerbated by climate change also cause coastal erosion and damage to mangroves, while reduced freshwater flows and salinity intrusion in the Sundarbans are threatening salt-sensitive mangrove tree species like *Heritiera formes*. This species is classified as Endangered (EN) by IUCN, while *Bruguiera hainesii* and *Sonneratia griffithii* are Critically Endangered (CR).

Today the Bay of Bengal mangroves cover ≈8% less than our broad estimation for 1970. The rate of decline has slowed since 2015 and, if the present rate persists, an overall decrease of -12% is projected over the next 50 years. However, they are expected to be resilient to even extreme sea-level rise scenarios, due to high sediment supply and vertical accretion. We estimate that 5% of the Bay of Bengal mangroves are undergoing degradation. This value could rise to 15% over a 50-year period based on decay of vegetation indexes.

Overall, the Bay of Bengal mangrove ecosystem is assessed as **Least Concern (LC).**

Citation:
Macintosh, D. J., Suárez, E. L., Aung, T., Friess, D.A, Lee, C., Hossain, M., Nightingale, M., & Valderrábano, M. (2023). '*IUCN Red List of Ecosystems, Mangroves of the Bay of Bengal*'. EcoEvoRxiv. https://doi.org/10.32942/X2930F

Corresponding author:
Email: marcos.valderrabano@iucn.org

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

Ecosystem classification:
MFT1.2 Intertidal forests and shrublands

Assessment's distribution:
The Bay of Bengal province

Summary of the assessment:

Criterion	A	B	C	D	E	Overall
Subcriterion 1	**LC**	**LC**	**DD**	**DD**	**NE**	
Subcriterion 2	**LC**	**LC**	**LC**	**LC**	**NE**	**LC**
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 Bay of Bengal LC

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_23 Mangroves of the Bay of Bengal

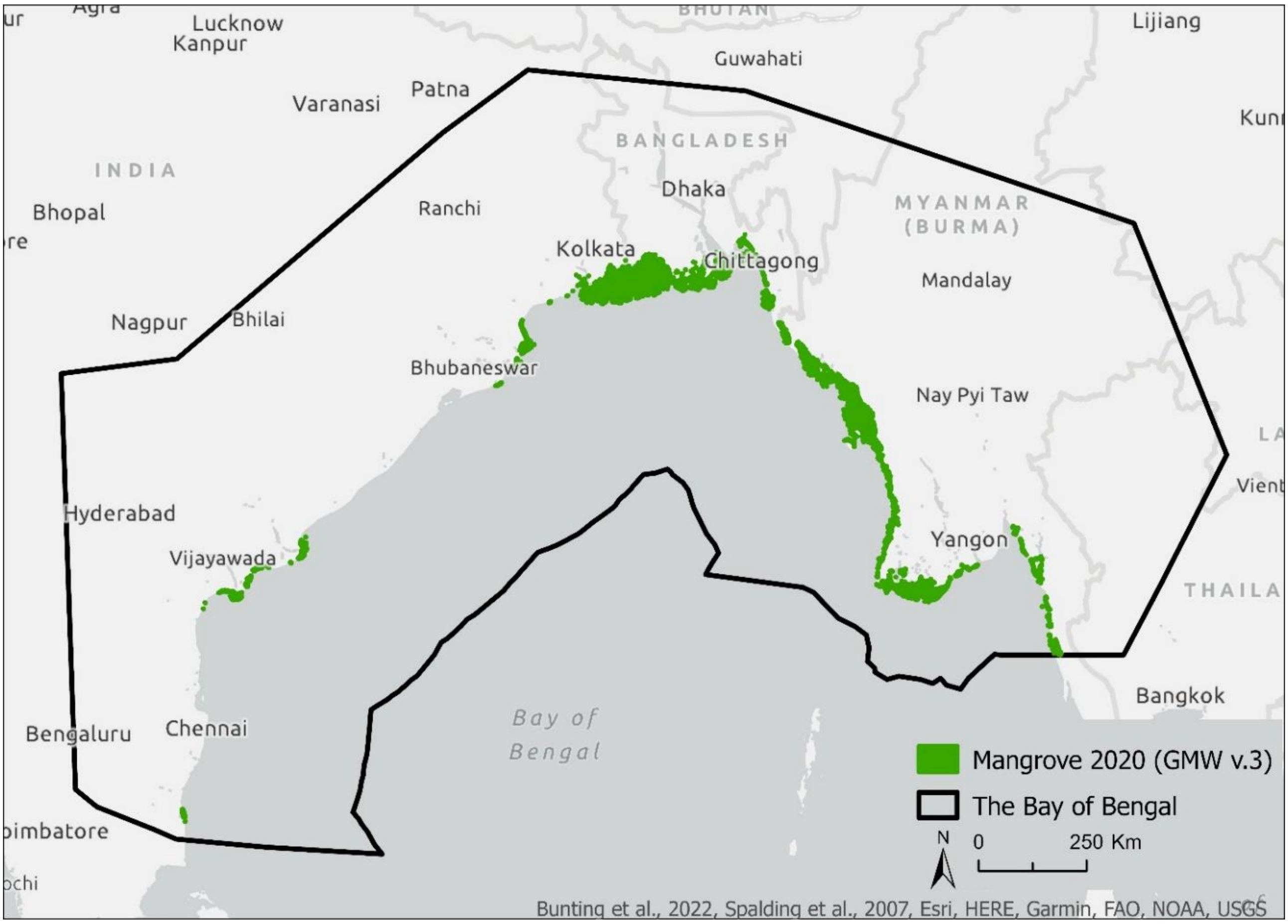
IUCN Habitats Classification Scheme (version 3.1, IUCN 2012) :

1 Forest

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

12 Marine Intertidal

12.7 Mangrove Submerged Roots



2. Ecosystem Description

Spatial distribution

The 'Mangroves of the Bay of Bengal' includes most of the coastline of eastern India (from Tamil Nadu to West Bengal), the whole coast of Bangladesh, and the northern and central coastal regions of Myanmar: including Rakhine State, the Ayeyarwady Delta and the Gulf of Mottama (Spalding *et al.*, 2007).

Mangroves are the dominant coastal ecosystem in this province, with an estimated extent of 10,250 km^2 in 2020, representing about 7% of the global mangrove area. There has been a -3.1% net loss of area since 1996 (from Bunting *et al.*, 2022).

Biotic components of the ecosystem (characteristic native biota)

The mangroves of the Bay of Bengal province are biologically diverse with 41 recorded true mangrove plant species (IUCN, 2022). There are at least 53 animal species within the taxa Actinopterygii, Aves, Chondrichthyes, Gastropoda, Mammalia and Reptilia associated with mangrove habitats in the Red List of Threatened Species database (IUCN, 2022) that have natural history collection records, or observations, within the distribution of this province (GBIF, 2021).

The Sundarbans mangrove flora is distinguished by the important timber tree, *Heritiera fomes*, as well as the tree species *Excoecaria agallocha*, *Ceriops decandra* and *Sonneratia apetala*. Two other mangrove species, *Bruguiera hainesii and Sonneratia griffithii*, are classified by IUCN as Critically Endangered (CR), with the largest known global population of *B. hainesii* existing in central Rakhine State (Myanmar), while *Heritiera fomes* is classified by IUCN as Endangered (EN). The Royal Bengal Tiger (*Panthera tigris*) is a keystone animal species of the Sundarbans mangrove ecosystem but is also classified by IUCN as Endangered (EN).

Estuarine mangroves in Kyaukphyu District, Rakhine State, Myanmar (Photo credit: Don Macintosh).

Abiotic Components of the Ecosystem

Mangroves are highly dynamic ecosystems influenced by interactions involving landscape position, climatic conditions (especially rainfall), hydrological processes, sea-level, sediment dynamics, subsidence, storm-driven processes and, in some degraded forests and mangrove plantations, disturbance by pests, predators or invasive species. High rainfall and an abundant sediment supply from rivers support extensive mangrove establishment and development, whereas waves and strong tidal currents destabilise and erode mangrove-supporting sediments, thereby mediating local-scale dynamics in ecosystem distribution. High rainfall reduces salinity stress and increases nutrient loading from adjacent catchments, while tidal flushing also regulates salinity.

Based on the typology of Worthington *et al.* (2020), the mangroves of the Bay of Bengal province can be classified as mainly deltaic and estuarine. The coastal deltas of the Ganges-Brahmaputra and Ayeyarwady river systems provide highly favourable salinity and sedimentary conditions for mangroves, resulting in these deltaic areas supporting some of the most extensive mangrove forests in the world. However, intense human activities in the Bay of Bengal province have altered some of these physical processes, leading to coastal erosion and negative impacts on mangrove structure, species composition and ecosystem integrity (Webb *et al.*, 2014; Richards and Friess, 2016). For example, a combination of human pressures (e.g., from shrimp farming) and climate change has contributed to salinization in the Bangladesh Sundarbans. The sundri mangrove (*Heritiera fomes*) and other freshwater swamp-associated species have declined there, while more salt-tolerant mangroves like *Avicennia marina*, as well as many invasive plant species, have colonized (Rahman, 2020).

A typical mangrove-fringed waterway in the Sundarbans: Bagerhat District, Bangladesh (Photo credit: Md. Kamal Hossain).

Key processes and interactions

Mangroves are structural engineers and possess traits, including pneumatophores, salt excretion glands, vivipary and buoyant propagules, that promote survival and recruitment in poorly aerated, saline, mobile and tidally inundated substrata. The extensive Sundarbans mangroves that have developed under these conditions play a vital role in protecting coastal areas from the destructive impact of the severe cyclones prevalent in the

Bay of Bengal. By greatly moderating tidal wave and wind forces, and by absorbing much of the torrential rainfall and flood waters during cyclonic storms, mangroves are credited with saving many human lives in this densely populated province. Mangroves produce large amounts of organic matter, mainly leaves, plus flowers, twigs and bark, which are broken down physically by tidal and marine processes, or consumed by crabs, then decomposed further by smaller invertebrates, fungi and bacteria to produce mangrove detritus, which provides a protein- and nutrient-rich food source for other consumers in the mangrove and coastal food web. The mangrove fauna also plays a key role in many other ecological processes, with crabs being among the most abundant and important mangrove-associated invertebrates. In addition to their role as mangrove herbivores and detritivores, crab burrows oxygenate sediments, enhance groundwater penetration, and provide habitats for other invertebrates. Specialised roots (pneumatophores, prop/aerial roots) provide important temporary habitats that protect juvenile fish from predators during high tides. They also serve as permanent habitats for the attachment of algae and sessile invertebrates (e.g., barnacles, oysters, mussels), as well as refuges for crabs and gastropods. Mangrove-associated mud crabs (*Scylla* spp.) are harvested in huge numbers from the Bangladesh Sundarbans and exported to major consumer centres in Southeast Asia. The mangrove vegetation provides habitats for numerous invertebrate herbivores, especially insects, as well as a diverse bird fauna, small mammals, and reptiles. Mangrove ecosystems are also major blue carbon sinks, incorporating organic matter into living biomass and sediments. Carbon storage in mangroves dominated by Sundri (*Heritiera fomes*) in the Bangladesh Sundarbans was estimated to be 360.1 ± 22.71 Mg C ha^{-1}, with up to 72% of the carbon being accumulated below ground (Rahman *et al.*, 2015). Similarly, the average soil carbon stock measured by Thant *et al*. (2012) in naturally regenerating mangroves and young mangrove plantations on former paddy land in the Ayeyarwady Delta was much higher (167 ±58 Mg C ha^{-1}) than in paddy soil without mangroves (85 ±17 Mg C ha^{-1}). The mangrove biomass carbon stock was 21.1 to 43.4 Mg C ha^{-1} in young plantations and 73.2 Mg C ha^{-1} in naturally regenerated mangroves (soil carbon equals at least 69.5% of the total = ecosystem carbon).

3. Ecosystem Threats and Vulnerabilities

A mangrove fuelwood pile typical of those seen in coastal villages in Rakhine State, Myanmar (Photo credit: Don Macintosh).

Intensive bag net fishing of shrimp seed for stocking in aquaculture ponds also destroys huge quantities of other mangrove-associated fish and shellfish larvae/juveniles: Satkhira District, Bangladesh (Photo credit: Don Macintosh).

Cattle grazing on agricultural land converted from mangroves in northern Rakhine State, Myanmar (Photo credit: Don Macintosh).

Main threatening process and pathways to degradation

The main causes of mangrove degradation in this province are illegal wood extraction and erosion caused by habitat conversion or storm impacts. In extreme cases, tree-cutting for timber and fuelwood can lead to deforestation. Encroachment into mangrove forest areas can also start the process leading to degradation and eventually deforestation. In addition to forest degradation caused by wood removal, intense fishery practices, including the use of very fine bag nets to trap shrimp seed for aquaculture ponds in Bangladesh and West Bengal, have severely degraded mangrove-associated aquatic resources (Das and Sarkar, 2009).

Estuarine mangroves converted to embanked shrimp ponds in Satkhira District, Bangladesh (Photo credit: Don Macintosh).

Mangrove habitat converted to extensive aquaculture ponds with embankments in Rakhine State, Myanmar (Photo credit: Don Macintosh).

Conversion of coastal habitat for agricultural or aquacultural uses has been the main driver of mangrove deforestation, especially in Myanmar (Webb *et al.*, 2014; Richards and Friess, 2016). Moreover, the widespread practice of constructing embankments (dykes) along coastlines and estuaries to prevent saltwater intrusion into agricultural land in this province has altered sediment dynamics significantly, leading to accelerated coastal erosion outside the dykes and sediment build-up on their landward side.

Climate change is a more recent and growing threat to this province’s mangrove ecosystems, especially their exposure to more frequent and severe storms and sea-level rise. 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).

The Bay of Bengal province is also affected severely by cyclones that can cause extensive shoreline erosion and damage large areas of mangrove forest. Recent devastating cyclones include Cyclone Nargis, which struck the Ayeyarwady Delta in 2008, while Cyclone Aila (2009), Cyclone Bulbul (2019) and Super Cyclone Amphan (2020) caused widespread damage to coastal districts in eastern India and Bangladesh. For example, it was reported that Super Cyclone Amphan destroyed more than 40 kilometres of shoreline and damaged more than 1,200 km^2 of the Sundarbans mangroves. Moreover, storm frequency and severity are increasing in this province due to climate change. Severe climatic events can also impact mangroves indirectly because storm-affected coastal communities may extract more mangrove wood to rebuild their damaged houses and village infrastructure, or to sell to offset their loss of other sources of livelihood.

Increasing water salinity is another threat specific to the Sundarbans mangrove forest, causing osmotic stress and leading, for example, to 'top dying' disease of trees (Rahman and Rahman, 2020). This is due to a combination of natural and man-made changes: dynamic movement of the Ganges-Brahmaputra riverine system eastwards, plus diversion of freshwater away from the coast for agricultural and domestic uses.

Definition of the collapsed state of the ecosystem

Mangroves are highly dynamic plant communities, with species distributions adjusting to local variations in tidal regimes and inundation, salinity gradients, or sedimentation processes. Changes that disrupt this dynamic can impact on key mangrove ecological functions. Ecosystem collapse is considered to occur when the tree cover of diagnostic species of true mangroves declines to zero (100% loss). Ecosystem collapse may occur under any of the following: a) changes in climatic conditions that damage or restrict recruitment and survival of diagnostic true mangroves; b) riverine and other freshwater inputs and/or waves and tidal currents that destabilise and erode sediments/soils and disrupt mangrove recruitment and growth; c) changes that cause salinity stress, or pollution. Examples of all these negative changes on mangroves can be seen in the Bay of Bengal province. Cyclone damage to mangroves and the phenomenon of 'top dying' of Sundri trees in the Sundarbans mangrove ecosystem due to salinity stress are particularly characteristic of this province. Conversion of mangroves to other forms of land use is the principal cause of ecosystem collapse in the Bay of Bengal province. This may be reversible in the case of conversion for agriculture or aquaculture by replanting mangroves, or by natural regeneration (e.g., Thant *et al.*, 2012), whereas mangrove loss due to infrastructural, industrial, or urban development is permanent. Cyclones can also impact significantly on mangroves in this province, particularly where the intertidal structure has already been affected by long-term erosion (Bhargava and Friess, 2022).

Threat Classification

IUCN Threat Classification (version 3.3, IUCN 2022) relevant to mangroves of the Bay of Bengal 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
- 6 Human Intrusions and Disturbances
    - 6.2 War, Civil Unrest & Military Exercises
- 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

Degraded and erosion-impacted mangrove vegetation in Rakhine State, Myanmar (Photo credit: Don Macintosh).

Mangrove forest in the Bangladesh Sundarbans damaged by Cyclone Aila in 2009. (Photo credit: Bangladesh Forest Department).

4. Ecosystem Assessment

Criterion A: Reduction in Geographic Distribution

Subcriterion A1 measures the trend in ecosystem extent during the last 50-year time period. 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. However, the estimated figures for 1970 should be considered only indicative (see appendix 3 for further details of the methods and limitations).

To estimate the Bay of Bengal mangrove area from 1996 to 2020, we used the most recent version of the Global Mangrove Watch spatial dataset (GMW v3.0). 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).

Results from the analysis of subcriterion A1 (Annex 3) show that the Bay of Bengal province has lost approximately 7.8% of its mangrove area over the last 50 years (1970-2020). Protection of the Sundarbans mangroves, which was declared a UNESCO World Heritage Site in 1987, and reforestation programmes in both India and Bangladesh (Gosh *et al.,* 2015), have contributed to limit the net area change in the Bay of Bengal province. These measures are reflected in the rate of net area change, which has slowed significantly since 2015 (GMW v3.0 dataset, Bunting *et al.,* 2022). Based on the information collected, the rate of change in the mangrove area was greater in India (0.5%/year) compared to Bangladesh (0.06%/year) and Myanmar (0.1%/year) (appendix 3). However, India accounts for only 25% of the Bay of Bengal mangrove area, and therefore has a lower impact on the overall area change compared to Bangladesh and Myanmar, which account for 43% and 30%, respectively. Overall, the net change in geographic distribution is below the 30% risk threshold, thus the ecosystem is assessed as **Least Concern (LC)** under subcriterion A1.

The Bay of Bengal	2020*	1970*	Net area Change (Km^2)	% Net Area Change	Rate of change (%/year)
	10,250	11,119	-868.40	-7.8%	-0.16%

** 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.*

Subcriterion A2 measures the change in ecosystem extent in any 50-year period, including from the present to the future: The Bay of Bengal province mangroves show a net area loss of -3% (1996-2020) based the Global Mangrove Watch time series (Bunting *et al.*, 2022). This value reflects the offset between areas gained (+0.21%/year) and lost (-0.34%/year). The largest decline in mangrove area occurred between 1996 and 2015; 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 -0.17 %/year (figure 1). Assuming this trend continues in the future, it is predicted that the extent of mangroves in the Bay of Bengal province will decrease by -8% from 1996 to 2046; by -12% from 1996 to 2070; but only by -9% from 2020 to 2070. Given that these predicted changes in mangrove extent are much less than the 30% risk threshold, the Bay of Bengal mangrove ecosystem is assessed as **Least Concern (LC)** under subcriterion A2.

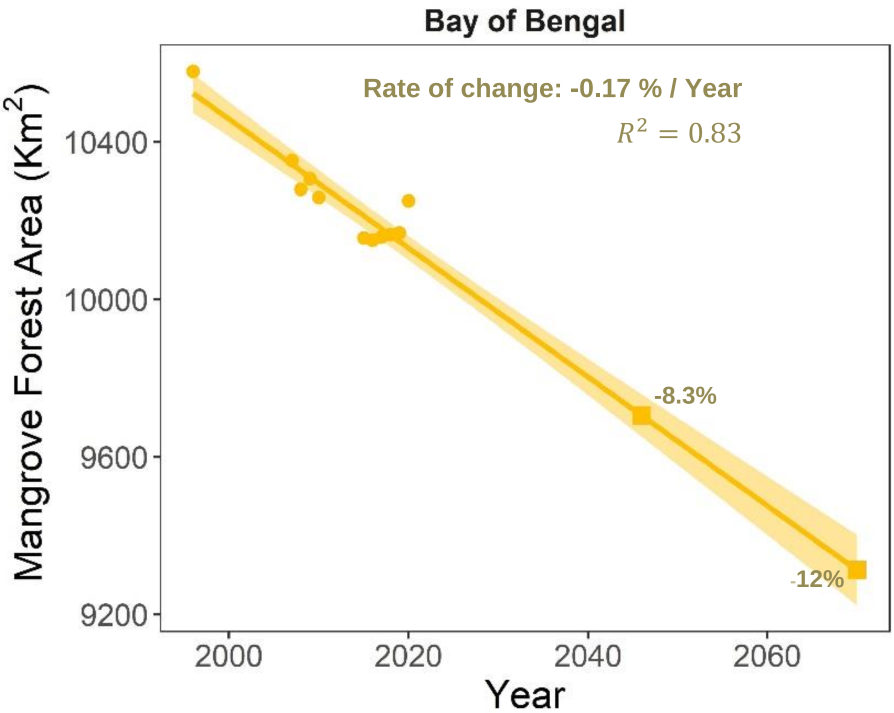


Figure 1. The Bay of Bengal province mangrove extent decline projected to 2070. Circles represent the province mangrove area between 1996 and 2020 based on the GMW v3.0 dataset and equations in Bunting *et al.*, 2022. The solid line and shaded area are the linear regression and 95% confidence intervals. Squares show the predicted mangrove area for 2046 and 2070.

Subcriterion A3 measures changes in mangrove area since 1750. A previous Red List of Ecosystems assessment of the Indian Sundarbans cited a decline of 71% of the mangrove area from 1776 to 2016 and assessed the ecosystem as "Vulnerable to Endangered" (Sievers *et al*., 2020). Unfortunately, there are no reliable data on the mangrove extent for the entire province during this period, and therefore the Bay of Bengal mangrove ecosystem is classified as **Data Deficient (DD)** for this subcriterion.

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

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). For 2020, based on the GMW v3.0 dataset for the Bay of Bengal province, AOO and EOO were measured as 521 grid cells 10 x 10 km and 1,458,882 km2, respectively (figure 2). 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 Bay of Bengal mangrove ecosystem is assessed as **Least Concern (LC)** under criterion B.

Province	Extent of Occurrence EOO (Km^2)	Area of Occupancy (AOO)	Criterion B
The Bay of Bengal	1,458,882	521	LC

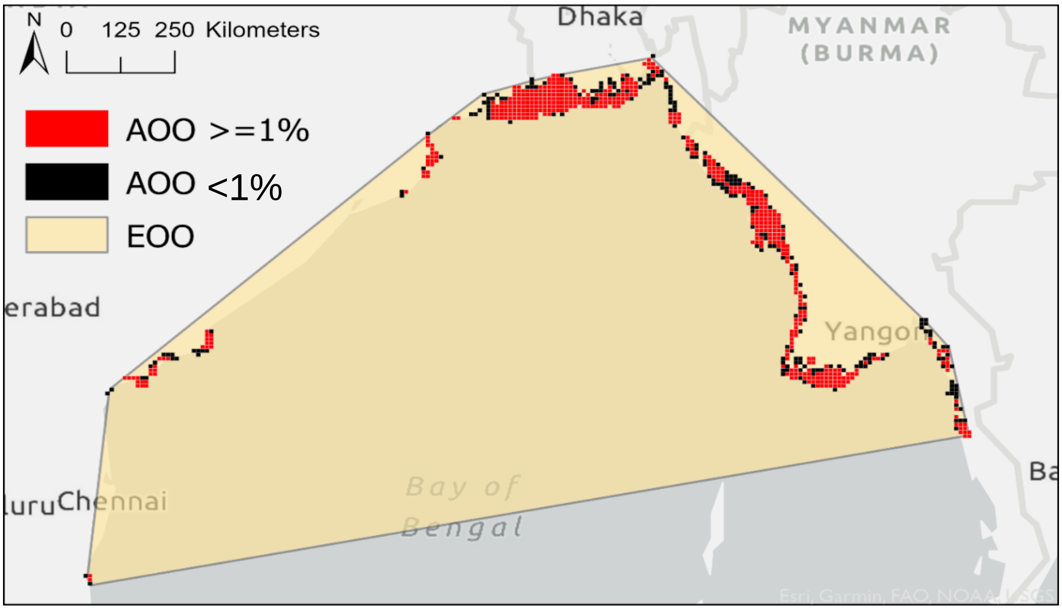


Figure 2. Bay of Bengal mangrove Extent Of Occurrence (EOO) and Area Of Occupancy (AOO) in 2020. Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022). The red 10 x 10 km grids are more than 1% covered by the ecosystem, and the black grids <1%.

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 Bay of Bengal 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: 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 Bay of Bengal mangrove 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), approximately 8% of the Bay of Bengal mangrove ecosystem would be submerged by 2070 (figure 3). According to the results reported by Lovelock *et al*. (2015), even under a more extreme SLR scenario (1.4 m SLR by 2100), the projected area to be submerged by 2070 remains below 30%.

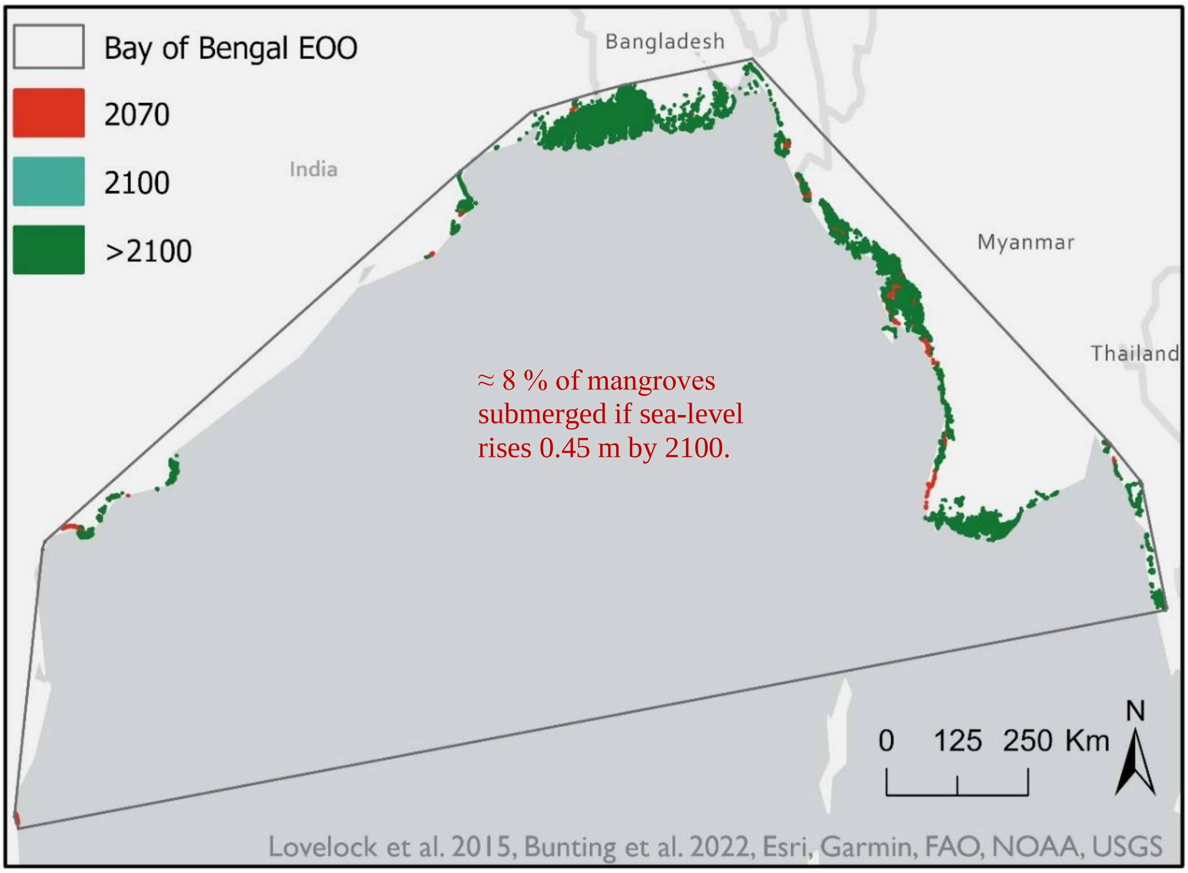


Figure 3. The Bay of Bengal mangrove forest predicted decade of submerge under IPCC RCP 6 scenario (0.45 m Global SLR by 2100), based on the model of Lovelock *et al*. (2015). Mangrove extent based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022).

Therefore, considering that no mangrove recruitment can occur in a submerged system (100% relative severity), but that less than 30% of the ecosystem extent will be affected by SLR, the Bay of Bengal Mangrove ecosystem is assessed as **Least Concern (LC)** 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 Bay of Bengal province is classified as Data Deficient (DD) for this subcriterion.

Overall, the ecosystem is assessed as **Least Concern (LC)** 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 Bay of Bengal 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 (30m 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 to 2017), 5.2% of the Bay of Bengal mangrove area is classified as degraded, resulting in an average annual rate of degradation of 0.31%. Assuming this trend remains constant, +15% of the Bay of Bengal mangrove area will be classified as degraded over a 50-year period. As less than 50% of the ecosystem will meet the category thresholds for criterion D, the Bay of Bengal 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 Bay of Bengal 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	**LC**	**DD**
B. Restricted Geo. Distribution	**B1** Extent of Occurrence	**B2** Area of Occupancy	**B3** # Threat-defined Locations < 5?
	LC	**LC**	**No**
C. Environmental Degradation	**C1** Past 50 years (1970)	**C2** Future or any 50y period	**C3** Historical (1750)
	DD	**LC**	**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	**LC**		

DD = Data Deficient; LC = Least Concern; NE = Not Evaluated

Overall, the status of the Bay of Bengal mangrove ecosystem is assessed as **Least Concern (LC).**

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Authors:

Macintosh, D. J., Suárez, E. L., Aung, T., Friess, D., Lee, C., Hossain, M., Nightingale, M., & Valderrábano, M.

Acknowledgments

The development of the Bay of Bengal Mangrove Red List of Ecosystems was made possible through the collaboration and dedication of the Asia Mangrove Specialists group. Their valuable contributions throughout the development process have been integral to the accuracy and quality of the final product.

We extend our sincere gratitude and appreciation to the mangrove specialists who participated in seven virtual workshops and provided valuable inputs during the completion of this ecosystem description and evaluation of the Red List of Ecosystems criteria: Aldrie Amir, Luzhen Chen, Nguyen Chu Hoi, I Wayan Eka Dharmawan, Dixon T. Gevaña, Sonjai Havanond, Pham Hong Tinh, Abu Naser Mohsin Hossain, Kyaw Thinn Latt, Win Maung, Meas Rithy, Severino G. Salmo III, Frida Sidik, Pham Trong Thinh and Thomas Worthington.

We would also like to thank the IUCN SSC Mangrove Specialist Group and the Global Mangrove Alliance Science Working group, for their support in the delineation of the level 4 mangrove units that were the basis for this analysis. Special thanks to José Rafael Ferrer-Paris for his contribution to the production of the general ecosystem description template for the RLE mangrove assessments.

We also wish to acknowledge Thomas Worthington for kindly providing the spatial data on mangrove degradation; Catherine Lovelock and Ruth Reef for the data modelling the future vulnerability to sea-level rise; as well as Md. Kamal Hossain and the Bangladesh Forest Department for generously providing us with some of the photographs included in this document.

Finally, we would like to thank the Keidanren Nature Conservation Fund (KNCF) for the financial support to carry out this project.

Peer revision:

PROVITA ONG

Web portal:

http://iucnrle.org/

7. Appendices

1. List of Key Mangrove Species

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

Class	Order	Family	Scientific name	RLTS category
Liliopsida	Arecales	Arecaceae	*Nypa fruticans*	LC
Liliopsida	Arecales	Arecaceae	*Phoenix paludosa*	NT
Magnoliopsida	Caryophyllales	Plumbaginaceae	*Aegialitis rotundifolia*	NT
Magnoliopsida	Ericales	Primulaceae	*Aegiceras corniculatum*	LC
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	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 gymnorhiza*	LC
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	*Kandelia candel*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora apiculata*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora mucronata*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora stylosa*	LC
Magnoliopsida	Malvales	Malvaceae	*Brownlowia argentata*	DD
Magnoliopsida	Malvales	Malvaceae	*Brownlowia tersa*	NT
Magnoliopsida	Malvales	Malvaceae	*Heritiera fomes*	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 apetala*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia caseolaris*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia griffithii*	CR
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 for Habitat 12.7 "Marine Intertidal – Mangrove Submerged Roots"; and with suitability recorded as "Suitable"; with "Major Importance" recorded as "Yes"; and with any value of seasonality except "Passage". We further filtered species with spatial point records in GBIF (some species are excluded due to a 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
Actinopterygii	Anguilliformes	Muraenidae	*Gymnothorax monochrous*	LC	Monochrome moray
Actinopterygii	Beloniformes	Zenarchopteridae	*Zenarchopterus ectuntio*	LC	
Actinopterygii	Clupeiformes	Clupeidae	*Sardinella melanura*	LC	Blacktip sardinella
Actinopterygii	Clupeiformes	Engraulidae	*Stolephorus andhraensis*	LC	Andhra anchovy
Actinopterygii	Elopiformes	Elopidae	*Elops hawaiensis*	DD	Giant herring
Actinopterygii	Elopiformes	Elopidae	*Elops saurus*	LC	Northern ladyfish
Actinopterygii	Gobiiformes	Eleotridae	*Butis amboinensis*	LC	Ambon gudgeon
Actinopterygii	Gobiiformes	Gobiidae	*Exyrias puntang*	LC	Puntang goby
Actinopterygii	Gobiiformes	Gobiidae	*Gobiopterus brachypterus*	DD	
Actinopterygii	Gobiiformes	Gobiidae	*Mahidolia mystacina*	LC	Flagfin prawn goby
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	*Taenioides buchanani*	DD	Burmese gobyeel
Actinopterygii	Gobiiformes	Gobiidae	*Taenioides cirratus*	DD	Whiskered eel goby
Actinopterygii	Perciformes	Blenniidae	*Omobranchus ferox*	LC	Gossamer blenny
Actinopterygii	Perciformes	Carangidae	*Atule mate*	LC	Yellowtail scad
Actinopterygii	Perciformes	Ephippidae	*Platax orbicularis*	LC	Orbiculate batfish
Actinopterygii	Perciformes	Gerreidae	*Gerres erythrourus*	LC	Deep-bodied mojarra
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus gibbosus*	LC	Brown 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	Lutjanidae	*Lutjanus fulviflamma*	LC	Dory snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulvus*	LC	Blacktail snapper
Actinopterygii	Perciformes	Sciaenidae	*Johnius carouna*	LC	Caroun croaker
Actinopterygii	Perciformes	Sciaenidae	*Nibea maculata*	LC	Blotched croaker
Actinopterygii	Perciformes	Sciaenidae	*Panna microdon*	LC	Panna croaker
Actinopterygii	Perciformes	Siganidae	*Siganus vermiculatus*	LC	Vermiculated spinefoot
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron manilensis*	LC	Narrow-lined puffer
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron reticularis*	LC	Reticulated pufferfish
Aves	Ciconiiformes	Ciconiidae	*Leptoptilos javanicus*	VU	Lesser adjutant
Aves	Columbiformes	Columbidae	*Ducula badia*	LC	Mountain imperial-pigeon

Class	Order	Family	Scientific name	RLTS category	Common name
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	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	Pachycephalidae	*Pachycephala cinerea*	LC	Mangrove whistler
Aves	Passeriformes	Pittidae	*Pitta megarhyncha*	NT	Mangrove pitta
Aves	Piciformes	Picidae	*Picus viridanus*	LC	Streak-breasted woodpecker
Aves	Suliformes	Anhingidae	*Anhinga melanogaster*	NT	Oriental darter
Chondrichthyes	Myliobatiformes	Dasyatidae	*Pateobatis bleekeri*	EN	Bleeker's whipray
Gastropoda	Ellobiida	Ellobiidae	*Ellobium aurisjudae*	LC	Judas ear cassidula
Gastropoda	Littorinimorpha	Littorinidae	*Littoraria undulata*	LC	[Robust shell]
Mammalia	Carnivora	Felidae	*Panthera pardus ssp. delacouri*	CR	Indochinese leopard
Mammalia	Carnivora	Felidae	*Panthera tigris*	EN	Tiger
Mammalia	Cetartiodactyla	Phocoenidae	*Neophocaena phocaenoides*	VU	Indo-Pacific finless porpoise
Reptilia	Squamata	Colubridae	*Ahaetulla fronticincta*	LC	River vine snake
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 Bay of Bengal 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 Bay of Bengal 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) and 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**
Bangladesh	4,484	4,482	4,341	4,339
India	4,038	2,621	5,350	3,472
Myanmar	5,435	3,148	5,711	3,308
The Bay of Bengal		**10,250**		**11,119**

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

Country	Year	Mangrove Area (Ha)	Reference
Bangladesh	1976	436,617	Islam, M.M., Borgqvist, H., & Kumar, L. (2019). Monitoring mangrove forest landcover changes in the coastline of Bangladesh from 1976 to 2015, Geocarto International, 34:13, 1458-1476. DOI: 10.1080/10106049.2018.1489423
Bangladesh	1989	462,182	Ibid.
Bangladesh	2000	461,170	Ibid.
India	1957	571,808	Mathauda, G.S. (1957). The mangrove of India. In Proceedings of the Mangrove Symposium. p. 66-97. Calcutta.
India	1980	506,702	FAO (2002). FAO's database on mangrove area estimates, By Wilkie, M.L., Fortuna, S., & Souksavat, O. Forest Resources Assessment Working Paper No. 62. Rome.
Myanmar	1972	571,100	Saenger, P., Hegerl, E.J., & Davie, J.D.S. (1983). Global status of mangrove ecosystems. Commission on Ecology Papers No.3. IUCN. Gland, Switzerland. 88 pp.
Myanmar	2020	5,435	Bunting *et al*., (2022). Global Mangrove Extent Change 1996–2020: Global Mangrove Watch Version 3.0. Remote Sensing 14 (15): 3657. doi.org/3390/rs14153657
For all countries.			FAO (2003). Status and trends in mangrove area extent worldwide. By Wilkie, M.L., & Fortuna, S. Forest Resources Assessment Working Paper No. 63. Forest Resources Division.