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Mangroves of the Andaman LC

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Abstract

The 'Mangroves of the Andaman' is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology) within the Andaman province. It includes intertidal forests and shrublands of the marine ecoregions of the Andaman and Nicobar Islands; the Andaman Sea Coral Coast of Myanmar and Thailand; and northwest Sumatra. The diverse biota is characterised by 43 species of true mangroves, plus many mangrove-associated plant species. Three mangrove species are in the IUCN Red List of Threatened Species: *Sonneratia griffithii, Bruguiera hainesii* and *Heritiera fomes.*

Mangroves in this province had a mapped extent of 4,938 km2 in 2020, representing 3.4% of the global mangrove resource by area. The Andaman mangroves are threatened widely by wood extraction, encroachment and conversion for agriculture or aquaculture, and by coastal infrastructure projects in more specific locations. They also face threats from climate change, mainly in the form of sea-level rise (SLR), especially along the northwest coast of Sumatra.

The Andaman mangrove ecosystem is thought to have undergone a major decline in extent around the early 20th century. Today the ecosystem covers 16% less than our broad estimations for 1970 based on national studies. However, the net area loss since 1996 is only -1.2% and there has been a further deceleration in area loss since 2015. Under a mid-high SLR scenario (IPCC RCP6) ≈21% of the Andaman mangroves would be submerged by 2070. Moreover, we estimated that 2.1% of the Andaman mangroves are undergoing degradation and this could rise to 6% over a 50-year period based on an analysis of the decay of vegetation indexes. These estimates are very conservative; however, there were no other data sources available to measure environmental degradation at the province level.

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

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

MFT1.2 Intertidal forests and shrublands

Assessment's distribution:

The Andaman province

Summary of the assessment:

Criteria	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

Ecosystem classification:

Mangroves of the Andaman 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_51 Mangroves of Andaman

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

Conserved primary mangrove forest in the Lampi Island Marine National Park in Tanintharyi Region of southern Myanmar: a stand of very tall Rhizophora trees (Photo credit: Toe Aung).

Conserved primary mangrove forest in the Lampi Island Marine National Park in Tanintharyi Region of southern Myanmar: a giant Bruguiera gymnorhiza tree (Photo credit: Toe Aung).

Only remnants remain of the primary mangrove forest that once existed on the Andaman coast of Thailand: a solitary giant Avicennia marina tree in Ranong Province (Photo credit: Don Macintosh).

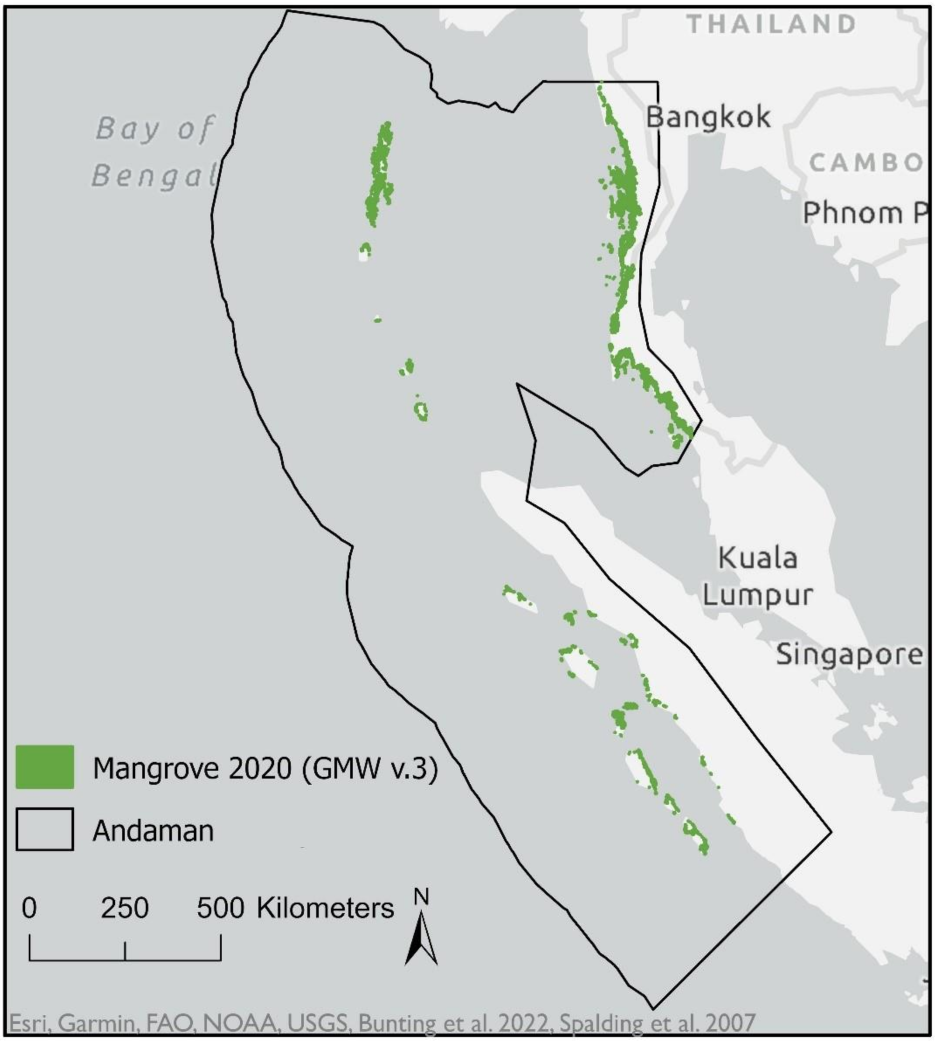
Regenerated secondary forest typical of most mangrove areas in the Andaman province, Ranong Province, Thailand (Photo credit: Don Macintosh).

2. Ecosystem Description

Spatial distribution

The 'Mangroves of the Andaman' (Andaman province) include intertidal forests and shrublands of the marine ecoregions of the Andaman and Nicobar Islands, Andaman Sea Coral Coast, the Myeik Archipelago and Western Sumatra (Spalding *et al.*, 2007). The coastline of this province extends across five countries and territories (India, Myanmar, Thailand, Malaysia, and Indonesia). The mangrove area was estimated to be 4,938 km^2 in 2020, representing a net loss of only -1.2% in area since 1996 (from Bunting *et al.* 2022). The Andaman mangroves contribute 3.4% of the global total mangrove resource. Based on the typology of Worthington *et al.* (2020), the Andaman mangroves are mainly open coast and estuarine formations. They include a globally important concentration of mangroves fringing the more than 800 islands of the Myeik Archipelago in the Tanintharyi Region of southern Myanmar.

In contrast to the extensive mangroves bordering the coastlines of southern Myanmar and the west coast of Thailand, mangroves within the Andaman province on the western coast of Sumatra are mostly restricted to estuaries and inlets behind sand dunes because this coastline is exposed to the open Indian Ocean. The northwest coast of Sumatra is more sheltered and includes Aceh Province, which was the epicentre of the earthquake that caused the 2004 tsunami. Although the tsunami destroyed or severely damaged about 30,000 ha of mangrove forest, simulation studies have shown that mangroves can significantly reduce the hydrodynamic force of more moderate tsunami waves (Yanagisawa *et al.* 2009).



Biotic components of the ecosystem (characteristic native biota)

The 'Mangroves of the Andaman' support a diverse biota that includes 43 true mangrove and many other key plant species (IUCN, 2022). According to the IUCN Red List of Threatened Species (IUCN, 2022), there are three threatened true mangrove species: *Sonneratia griffithii* (CR = Critically Endangered), *Bruguiera hainesii* (CR) and *Heritiera fomes* (EN = Endangered).

Due to extensive wood extraction for timber and fuelwood (especially mangrove charcoal), the Andaman mangroves consist mainly of secondary growth forests resulting from natural or assisted regeneration, or plantation trees. However, some remnants of the tall primary mangrove forests remain in southern Myanmar and southern Thailand.

There are at least 75 animal species in the taxa Actinopterygii, Aves, Gastropoda, Insecta, Magnoliopsidae and Reptilia that have been associated with mangrove habitats in the Red List of Threatened Species (IUCN 2022) database and have natural history collection records or observations within the distribution of this province (GBIF, 2021). Several mangrove-associated bird species are threatened, such as the Endangered (EN) milky stork (*Mycteria cinerea*) and Critically Endangered (CR) silvery pigeon (*Columba argentina*). One of the world’s largest snakes, the Burmese python (*Python bivittatus*), which is found in a wide range of water-dominated habitats including mangroves, is classified by IUCN as Vulnerable (VU). Large earth mounds of the mud lobster (*Thalassina* spp.) are a feature of the Andaman coast mangroves in Thailand, where they provide micro-habitats for many other plant and animal species (Ngokoed and Ratmuangkhwang, 2020) and aid in the transition from back mangrove to terrestrial habitat.

Abiotic components of the ecosystem

Mangroves are highly dynamic ecosystems influenced by interactions among landscape position, climatic conditions (especially rainfall), hydrological processes, sea-level, sediment dynamics, subsidence, storm-driven processes and, in the case of degraded mangroves and some mangrove plantations, invasive species or disturbance by pests and predators. Rainfall and sediment supply from rivers and currents promote mangrove establishment and persistence, while waves and strong tidal currents destabilise and erode mangrove substrata, thereby mediating local-scale dynamics in ecosystem distribution.

High and protracted rainfall reduces salinity stress and increases nutrient loading from adjacent catchments, while tidal flushing also regulates salinity. Such favourable environmental conditions for mangroves are present in Ranong Province, the wettest province in Thailand, where the average annual rainfall is 4000 to 5000 mm; there are 190 days with rainfall each year and the tidal range exceeds 4 m (Macintosh *et al.*, 1991). These climatic and tidal conditions in Ranong moderate the ambient temperature and soil and water salinities allowing mangrove trees to flourish, where they form the largest single extent of mangroves remaining in Thailand. Moderate salinities favourable to mangroves also prevail on the coasts of southern Myanmar and northwest Sumatra.

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 sediments. Mangroves produce large amounts of organic matter, especially leaves, plus flowers, twigs and bark, which are broken down physically by tidal and marine processes, or consumed by crabs, then decomposed further by fungi and bacteria to produce mangrove detritus as a protein- and nutrient-rich food source for other consumers in the mangrove and coastal food web. The mangrove fauna plays a key role in many other ecological processes, with crabs being among the most abundant and important mangrove-associated invertebrates. Their burrows oxygenate sediments, enhance groundwater penetration, and provide habitat for other invertebrates such as molluscs and worms. Specialised roots (pneumatophores, prop/aerial roots) provide important temporary habitats during high tides that protect juvenile fish from predators. They also serve as permanent habitats for the attachment of algae and sessile fauna (e.g., barnacles, oysters, mussels) as well as refuges for crabs and gastropods. Mangrove canopies support invertebrate herbivores and other terrestrial biota including reptiles, small mammals, and extensive bird communities. Mangrove ecosystems are also major blue carbon sinks, incorporating organic matter into sediments and living biomass. Carbon storage of up to 299 Mg C/ha-1 has been reported in primary Rhizophora-dominated forests in Tanintharyi, southern Myanmar; and 131-188 Mg C/ha-1 in mixed secondary mangrove in Tanintharyi and southern Thailand (Win

Maung Aye, 2020; Meepol, 2020). The soils in these mangrove forests are also rich in organic matter (up to 22% by weight) and the average storage of soil carbon is estimated to be 300 to more than 400 Mg C/ha-1 to a depth of one metre (based on Macintosh *et al.* (1991); Sanderman *et al.* (2018); Elwin *et al.* (2019).

3. Ecosystem Threats and Vulnerabilities

Main threatening process and pathways to degradation

Extensive areas of mangrove forest in this province have been converted to agriculture or aquaculture, especially oil palm plantations and shrimp farms, respectively. Human encroachment into mangrove areas and coastal industrial and other infrastructure development, including for coastal tourism, are threats to mangroves on a more localised scale. There is also a serious problem of mangrove degradation in southern Myanmar (Tanintharyi Region) caused by charcoal production for export to Thailand. The large-scale and mainly illegal cutting of mangroves in Tanintharyi is the result of a ban on domestic mangrove charcoal production imposed in Thailand about 25 years ago, plus a shortage of mangrove wood for domestic charcoal production in other regions of Myanmar (Yan, 2019). Climate change is a more recent and growing threat to the region'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).

Encroachment and degradation of mangroves resulting from the numerous coastal villages in Tanintharyi region, southern Myanmar, where villagers are almost entirely dependent on mangrove wood and mangrove-associated aquatic resources (Photo credit: Don Macintosh).

Definition of the collapsed stated of the ecosystem.

Mangroves are highly dynamic ecosystems, with species distributions adjusting to local changes in tidal regimes and local inundation, salinity gradients or sedimentation processes. Changes that disrupt these dynamics can lead to ecosystem collapse, which is considered to occur when the tree cover of diagnostic species of true mangroves declines to zero (100% loss). In the Andaman province, encroachment and illegal tree-felling typically result in the removal of large, true mangrove species (especially *Rhizophora* trees, which are highly valued for charcoal, firewood, pole wood and timber). This diminishes the reproductive and recruitment potential of the mangrove forest. Gaps caused by tree removal are often colonised by opportunist or invasive mangrove-associates e.g., *Acrostichum aureum, Derris trifoliata*, *Phoenix paludosa*, which further impedes recruitment and regeneration of true mangrove species. In addition to destroying mangrove habitat directly, coastal agriculture and aquaculture developments that involve construction of earthen embankments and canals for water management may severely impact adjacent mangroves by disrupting the natural hydrological regime, including diverting freshwater, inhibiting tidal water movements, and reducing water-borne sediment deposition. These changes can lead to mangrove ecosystem collapse from several causes e.g., salinity stress, soil erosion, impaired recruitment of true mangroves, and waterlogging of mangroves within embanked areas. Due to the high and protracted rainfall regime in most coastal areas of the Andaman province, soil erosion is a serious threat where mangroves have been destroyed or degraded. This province is also vulnerable to climate change-induced sea-level rise, which is adding to the risk of soil erosion and coastal habitat inundation. The coastline of northwest Sumatra is particularly vulnerable in this regard. Some islands off the coast of Aceh Province have already become permanently submerged by sea-level rise, while coastal erosion and flooding of low-lying coastal habitats are predicted to become more severe (e.g., Al'ala and Syamsidik, 2019).

Degraded secondary mangrove forest in Auckland Bay, Tanintharyi Region, Myanmar impacted by tree removal for charcoal production and other uses (Photo credit: Don Macintosh).

An intensive soft-shell crab farm built in a former mangrove area in Tanintharyi Region, Myanmar. Crab aquaculture has also created huge demand for under-sized mud crabs resulting in severe mangrove over-fishing (Photo credit: Don Macintosh).

Threat Classification

IUCN Threat Classification (version 3.3, IUCN 2022) relevant to mangroves of the Andaman 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

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 extent of the Andaman 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).

Results from the analysis of subcriterion A1 (Annex 3) show that the Andaman province has lost approximately 16% of its mangrove area over the past 50 years (1970-2020). This modest loss can be attributed to the low net area change in Myanmar's mangrove forest area (5%), which accounts for 46% of the total extent of the Andaman mangroves. Additionally, recent data from Global Mangrove Watch (Bunting *et al.*, 2022) indicate a deceleration in Myanmar' net area change since 2015 due to a trade-off between area gains and losses. In contrast, while the coasts of northwest Sumatra and northern Malaysia experienced a much higher percentage net change in mangrove area (25-31% loss), their combined area represents only 17% of the total mangrove extent in the Andaman province. The loss of 16% in mangrove area is less than the 30% risk threshold, thus the Andaman mangrove ecosystem is assessed as **Least Concern (LC)** under subcriterion A1.

The Andaman	2020*	1970*	Net area Change (Km^2)	% Net Area Change	Rate of change (%/year)
	4,938	5,900	-962	-16.3%	-0.3%

**Details on the methods and references used to estimate the mangrove area in 1970 are listed in appendix 3. For 2020, the total mangrove area within the province was estimated using the Global Mangrove Watch Version 3 (GMW v3.0) dataset.*

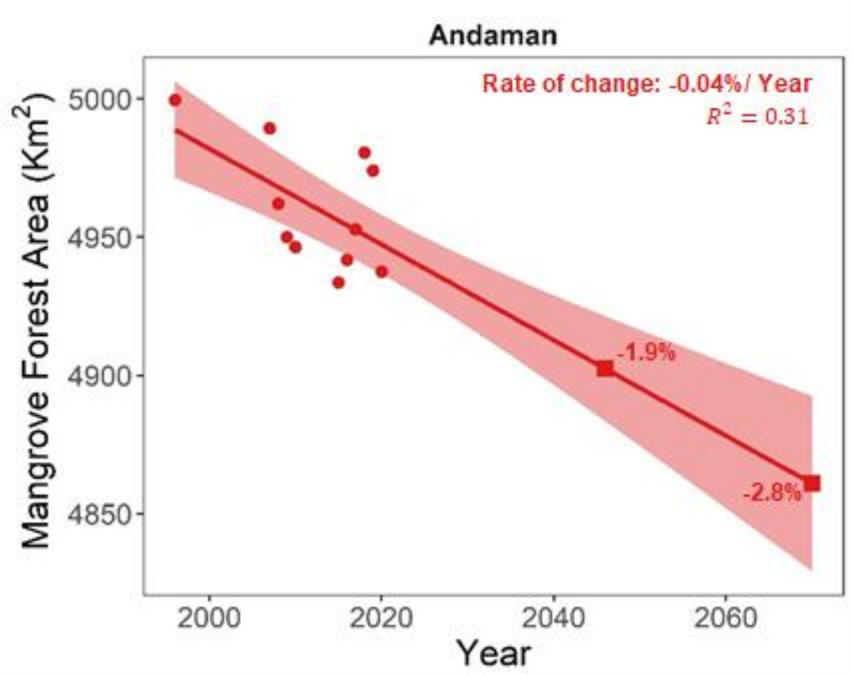


Figure 1. Andaman province mangrove extent decline projected to 2070. Circles represent the province mangrove area between 1996 and 2020. Estimates based on GMW v3.0 dataset and equations in Bunting *et al.* 2022. The solid line and shaded area are the linear regression and 95% confidence interval. Squares show the Andaman province mangrove area predicted 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=0.308).

Subcriterion A2 assesses the change in ecosystem extent in any 50-year period, including from the present to the future: the Andaman province mangroves show a net area change of ≈ -1% (1996-2020) based on the GMW v3.0 dataset (Bunting *et al.*, 2022). This value reflects the offset between areas gained (+0.07%/year) and lost (-0.12%/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 -0.04% per year (figure 1). Assuming this trend continues, it is predicted that the extent of mangroves in the Andaman province will decrease by -1.9% from 1996 to 2046; by -2.8% from 1996 to 2070; but only by -1.6% from 2020 to 2070. Given that these predicted changes in mangrove extent are much less than the 30% risk threshold, the Andaman mangrove 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 Andaman mangroves 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 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
Andaman	1,067,679	426	LC

For 2020 the Andaman province AOO and EOO were measured as 426 grid cells 10 x 10 km and 1,067,679 km^2 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.

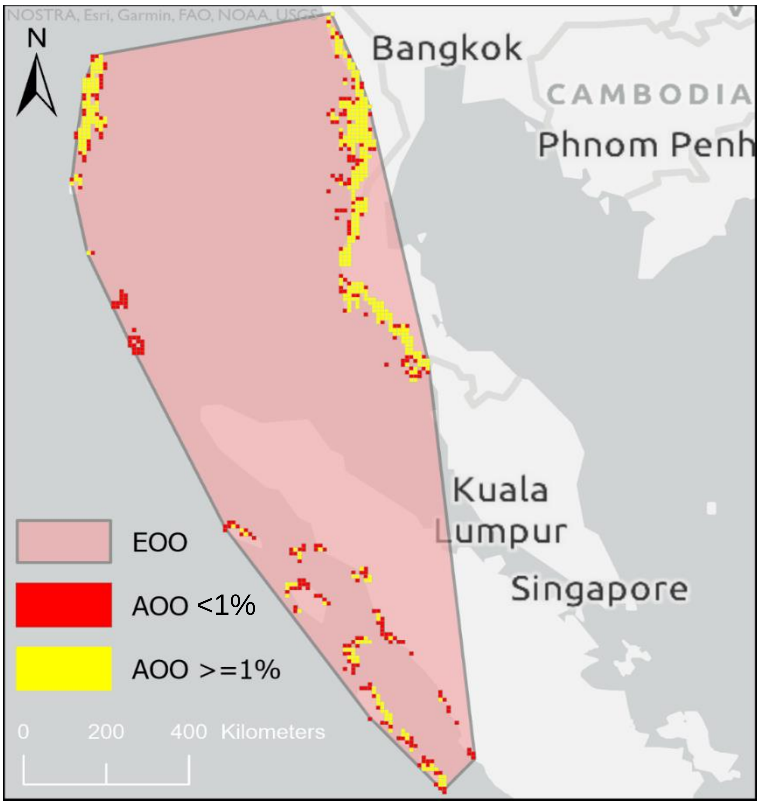


Figure 2. 2020 Andaman mangrove Extent Of Occurrence (EOO) and Area Of Occupancy (AOO). Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al*., 2022). The yellow 10 x 10 km grids are more than 1% covered by the ecosystem, and the red grids <1%.

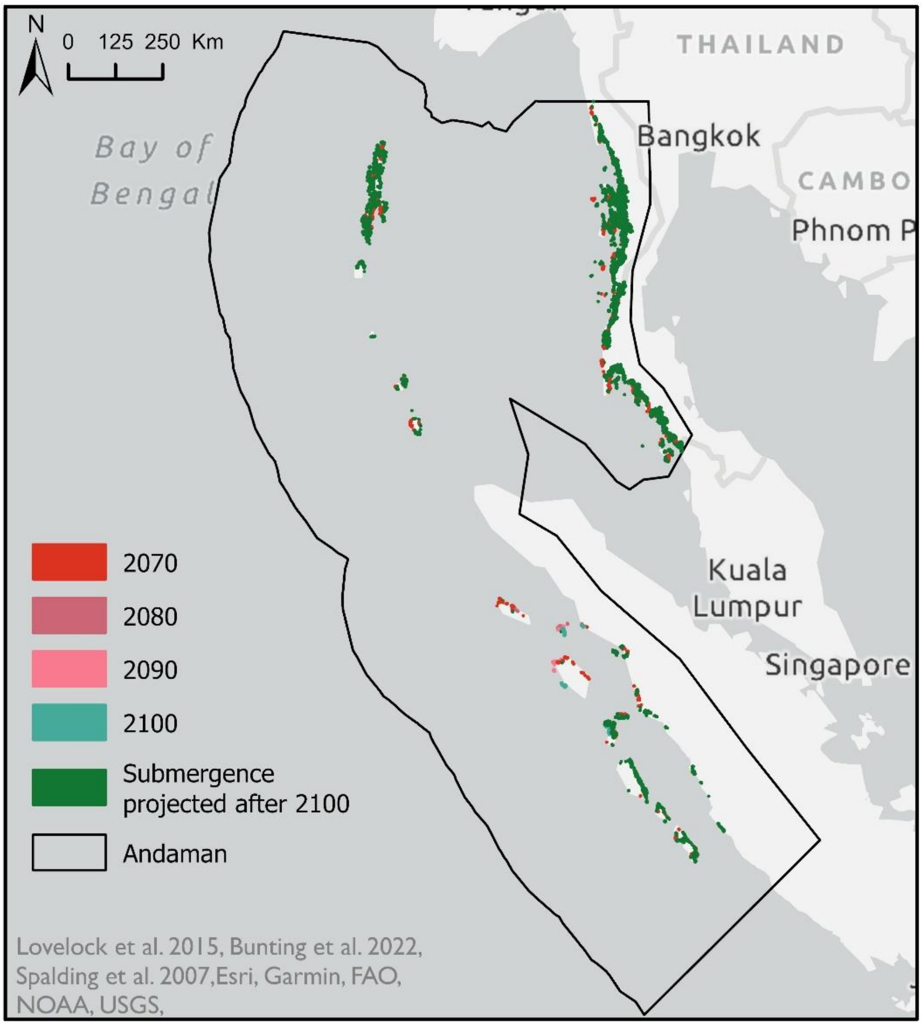
As a result, the Andaman mangrove ecosystem is assessed as **Least Concern (LC)** under criterion B.

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 Andaman 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 Andaman mangrove province (2020 spatial layer, GMW v3.0 dataset) 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.



≈ 21% submerged mangrove if sea - level rises 0.45 m by 2100.

Figure 3. Andaman 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).

Using this model and considering a plausible mid-high SLR scenario (IPCC RCP6, 0.45 m SLR by 2100), ≈21% of the Andaman mangrove ecosystem is projected to 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 is below the 30% extent of decline. Therefore, considering that no mangrove recruitment can occur in a submerged system (100% relative severity), but less than 30% of the ecosystem extent is affected by SLR, the Andaman 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 environmental degradation data covering the entire province, and therefore the Andaman 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 Andaman 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 12 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 observed changes 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), 2.1% of the Andaman mangrove area has degraded, resulting in an average annual rate of degradation of 0.13%. Assuming that this trend remains constant, + 6% of the Andaman mangrove area will be classified as degraded in a period of 50 years. Less than 50% of the ecosystem will meet the category thresholds for criterion D. 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 Andaman 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	**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 Andaman mangrove ecosystem is assessed as **Least Concern (LC)**.

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7. Appendices

1. List of Key Mangrove Species

List of plant species considered true mangroves or key plant species in mangrove communities according to 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 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 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	*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

Class	Order	Family	Scientific name	RLTS category
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia caseolaris*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia griffithii*	CR
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia ovata*	NT
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 (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". We further filtered species with spatial point records in the 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
Magnoliopsida	Fabales	Fabaceae	*Cynometra ramiflora*	LC	
Actinopterygii	Albuliformes	Albulidae	*Albula vulpes*	NT	Bonefish
Actinopterygii	Anguilliformes	Muraenidae	*Gymnothorax monochrous*	LC	Monochrome moray
Actinopterygii	Anguilliformes	Muraenidae	*Uropterygius concolor*	LC	Brown moray eel
Actinopterygii	Atheriniformes	Phallostethidae	*Phenacostethus posthon*	LC	
Actinopterygii	Beloniformes	Zenarchopteridae	*Zenarchopterus ectuntio*	LC	
Actinopterygii	Beloniformes	Zenarchopteridae	*Zenarchopterus gilli*	LC	Shortnose river garfish
Actinopterygii	Clupeiformes	Engraulidae	*Encrasicholina punctifer*	LC	Buccaneer anchovy
Actinopterygii	Clupeiformes	Engraulidae	*Thryssa kammalensis*	DD	[Kammal thrysa]
Actinopterygii	Gobiiformes	Eleotridae	*Butis amboinensis*	LC	Ambon gudgeon
Actinopterygii	Gobiiformes	Eleotridae	*Butis gymnopomus*	LC	Striped crazy fish
Actinopterygii	Gobiiformes	Gobiidae	*Cryptocentrus leptocephalus*	LC	Pink-speckled shrimpgoby
Actinopterygii	Gobiiformes	Gobiidae	*Exyrias puntang*	LC	Puntang goby
Actinopterygii	Gobiiformes	Gobiidae	*Glossogobius circumspectus*	LC	Circumspect goby
Actinopterygii	Gobiiformes	Gobiidae	*Gobiopterus brachypterus*	DD	
Actinopterygii	Gobiiformes	Gobiidae	*Mahidolia mystacina*	LC	Flagfin prawn goby

Class	Order	Family	Scientific name	RLTS category	Common name
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	*Taenioides buchanani*	DD	Burmese gobyeel
Actinopterygii	Gobiiformes	Gobiidae	*Taenioides cirratus*	DD	Whiskered eel Goby
Actinopterygii	Perciformes	Apogonidae	*Yarica hyalosoma*	LC	Mangrove Cardinalfish
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	*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	Microdesmidae	*Parioglossus raoi*	LC	Yellow dartfish
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

Class	Order	Family	Scientific name	RLTS category	Common name
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	*Phaenicophaeus sumatranus*	NT	Chestnut-bellied malkoha
Aves	Galliformes	Megapodiidae	*Megapodius freycinet*	LC	Dusky scrubfowl
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	Muscicapidae	*Cyornis rufigastra*	LC	Mangrove blue-flycatcher
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
Gastropoda	Cycloneritida	Neritidae	*Neritodryas subsulcata*	DD	Weakly cut nerite
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]
Reptilia	Squamata	Colubridae	*Ahaetulla fronticincta*	LC	River vine snake
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 Andaman 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 Andaman 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**
India	4,038	564	5,350	748
Indonesia	29,534	310	42,510	446
Malaysia	5,246	34	7,357	48
Myanmar	5,435	2,291	5,723	2,412
Thailand	2,528	1,738	3,267	2,246
The Andaman		**4,938**		**5,900**

Table b. List of selected studies considered to have reliable information on mangrove area for the period around 1970 in each country of the Andaman 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
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.
Indonesia	1982	4,251,011	Forestry Department (1982).
Malaysia	1975	688,634	FAO (1982). Management and utilization of mangroves in Asia and the Pacific. FAO environment paper 3. 160 pp.
Malaysia	1977	655,572	De la Cruz, A.A. (1984). A realistic approach to the use and management of mangrove areas in Southeast Asia. In: Teas, H.J., (ed.) Physiology and management of mangroves. Dr. W. Junk Publishers, The Hague. The Netherlands.
Malaysia	1978	637,739	Ong, J.E. (1978). *Mangroves in Malaysia*. Cited by Snedaker, S.C. (1984): The mangroves of Asia and Oceania: status and research planning. In: Proceedings of the Asian Mangrove Symposium. Soepadmo, E., Rao, A.N., & Macintosh, D.J. (eds.) 24-29 August 1980, Kuala Lumpur, Malaysia. pp. 5-15.
Malaysia	1979	652,219	Sasekumar, A. (1980). Status report on impact of pollution on mangrove ecosystems and related research programmes in Malaysia. Federation of Institutions for Marine and Freshwater Sciences.
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.
Thailand	1973	312,732	Vibulsresth, S., Ketruangrote, C., & Sriplung, N. (1976). Distribution of mangrove forest as revealed by earth resources technology satellite (ERTS-1) imagery. Paper presented at the Seminar/Workshop on Mangrove Ecology, 10-15 January 1976, Phuket, Thailand.

Country	**Year**	**Mangrove Area (Ha)**	**Reference**
Thailand	1960	372,448	Royal Forestry Department, Land Development Department and National Research Institute (1995). The Ninth National Seminar on Mangrove Ecology, Natural Research Council of Thailand. Royal Forestry Department, Land Development Department & National Research Institute.
Thailand	1961	368,100	Sukwong, S (1976). Status Report on the floristic and forestry aspects of mangrove in Thailand. Paper presented at the Seminar /Workshop on Mangrove Ecology, 10-15 January 1976, Phuket, Thailand. 8pp.
For all countries.			FAO (2003). Status and trends in mangrove area extent worldwide. By Wilkie, M.L. and Fortuna, S. Forest Resources Assessment Working Paper No. 63. Forest Resources Division.