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Mangroves of the South China Sea EN

Donald J. Macintosh[1,2], Ena L. Suárez[3], Luzhen Chen[4], Pham Hong Tinh[5], Maeve Nightingale[6] & 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, Gland 1196, Switzerland.*
[3] *Red List of Ecosystems Team, International Union for Conservation of Nature IUCN, Gland 1196, Switzerland.*
[4] *Key Laboratory of the Ministry of Education for Coastal and Wetland Ecosystems, College of the Environment and Ecology, Xiamen University, Fujian 361102, China.*
[5] *Hanoi University of Natural Resources and Environment, Hanoi, Viet Nam.*
[6] *International Union for Conservation of Nature IUCN Asia Regional Office, Bangkok 10110, Thailand.*

Abstract:

The 'Mangroves of South China Sea' is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology in the South China Sea province. It includes intertidal forests and shrublands of the marine ecoregions of the Gulf of Tonkin, South China Sea Oceanic Islands and Southern China.

The diverse biota of this ecoregion is characterised by 42 species of true mangroves, plus many associated taxa. There is a significant decline in species diversity with increasing latitude towards the northern limit of mangroves in Fujian Province. Two species: *Avicennia rumphiana* and *Camptostemon philippinensis* are in the IUCN Red List of threatened species.

The South China Sea ecoregion mangroves are mainly scattered open coast and estuarine formations, except in the Red River Delta. Their mapped extent in 2020 was 543 km^2 representing only 0.4% of the global mangrove resource. The current threats to mangroves are mainly from coastal urbanisation and industrialisation, sea dyke construction, pollution, and climate-related impacts, especially from typhoons, which occur frequently in this province.

Today, the South China Sea mangroves cover ≈36% less than in 1970 based on national studies. The South China Sea mangroves are also threatened by sea-level rise (SLR). Under a mid-high SLR scenario, and considering the limited coastal sediment supply, 50% of the mangrove area will be submerged by 2070. Moreover, we estimate that ≈3.5% of the mangroves are undergoing degradation. Based on analysis of the decay of vegetation indexes, this could rise to 10.2% over a 50-year period. These estimates are very conservative; however, no other data sources were available to measure environmental degradation at the ecoregion level.

Considering the significant effect of future SLR, the South China Sea mangroves are assessed as **Endangered (EN).**

Citation:

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

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

Ecosystem classification:

MFT1.2 Intertidal forests and shrublands

Assessment's distribution:

The South China Sea province

Summary of the assessment

Criterion	A	B	C	D	E	Overall
Subcriterion 1	VU	LC	DD	DD	NE	
Subcriterion 2	DD	LC	EN	LC	NE	EN
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 South China Sea EN

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_25 Mangroves of the South China Sea

IUCN Habitats Classification Scheme (Version 3.1):

1 Forest

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

12 Marine Intertidal

12.7 Mangrove Submerged Roots

Mangrove forest near Ha Long City, Quang Ninh Province, Viet Nam (Photo credit: Pham Hong Tinh).

Mangrove forest in Zhangjiang Estuary in Yunxiao County, Fujian Province, China (Photo credit: Haoliang Lu).

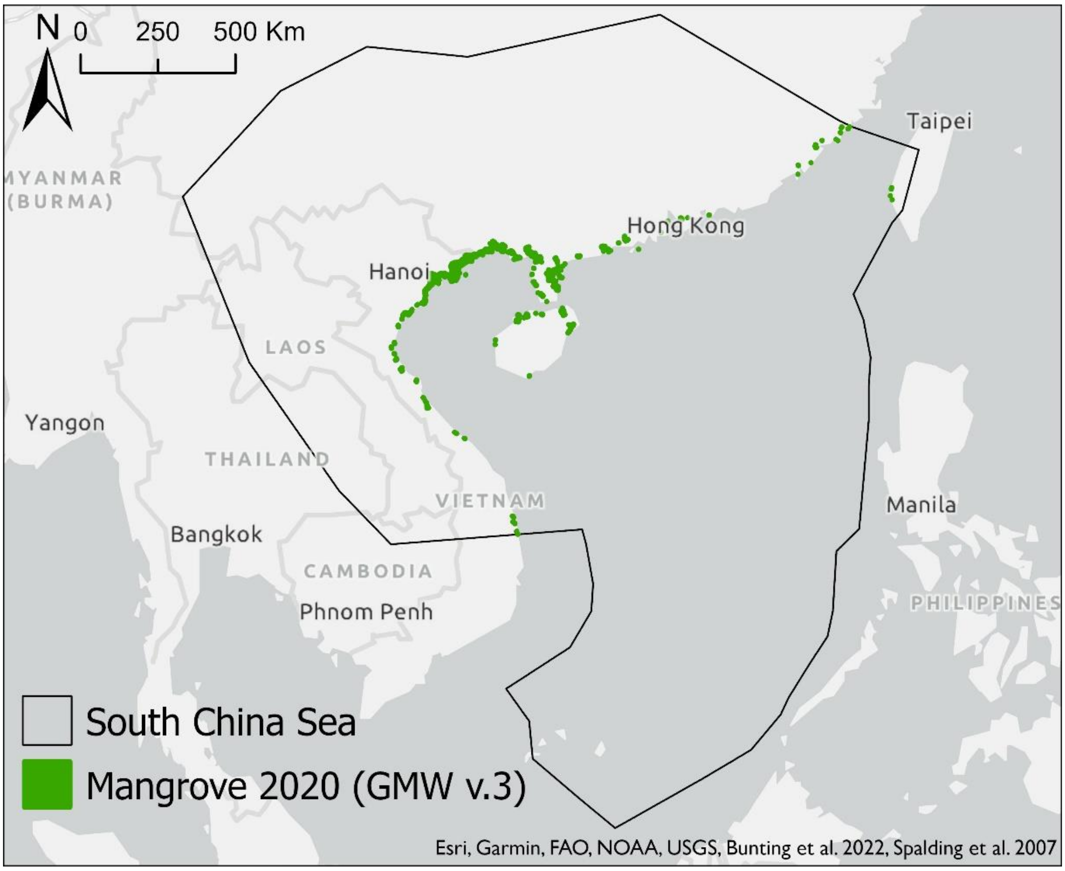
Mangrove forest formed by Bruguiera sexangula trees in Dongzhaigang near Haikou City, Hainan Province, China (Photo credit: Luzhen Chen).

2. Ecosystem Description

Spatial distribution

The 'Mangroves of South China Sea' include intertidal forests and shrublands of the marine ecoregions of the Gulf of Tonkin, South China Sea Oceanic Islands and Southern China within the South China Sea province. This province includes the coastline of central and northern Viet Nam, the southern coast of mainland China, Hainan Island, Hong Kong and most of the west coast of Taiwan (Spalding *et al.*, 2007). Based on the typology of Worthington *et al.*, (2020), the mangroves of this province are mainly open coast or estuarine formations, except in the Red River Delta, which has extensive deltaic mangroves. The mangrove area in 2020 was 543 km^2 and the net area lost from 1996 to 2020 was -4.5% (from Bunting *et al.*, 2022). Other than a concentration of mangroves in the Red River Delta, the spatial distribution of the mangroves in the South China Sea province is rather scattered and patchy. Their contribution to the total global mangrove resource is only 0.4%.

The South China Sea province is impacted severely by typhoons that originate in the Pacific Ocean. However, the Red River Delta and southern coast of China mangroves are protected to some extent by the land mass of Hainan Island. Mangroves in Taiwan are restricted to the sheltered western coast and most mangrove stands in Hong Kong are found in the northwest (Deep Bay region) and within other sheltered bays and mud flats (Tam and Wong, 2002). There are no mangroves on the exposed eastern Pacific Ocean-facing coastline of Taiwan because it is steep and rocky (Fan, 2002).



Biotic components of the ecosystem (Characteristic native biota)

The biota of 'Mangroves of the South China Sea' is characterised by the presence of 42 true mangrove plus other key associated plant species (IUCN, 2022). They include two species classified by IUCN as threatened: *Avicennia rumphiana* (VU = Vulnerable) and *Camptostemon philippinensis* (EN = Endangered). However, several other species are locally threatened, especially in China. There are at least 59 animal species in the taxa Actinopterygii, Aves, Chondrichthyes, Magnoliopsida, Mammalia and Reptilia that have been associated with mangrove habitats in the Red List of Threatened Species database (IUCN, 2022) and have natural history collection records or observations within the distribution of this province (GBIF, 2022).

There is a pronounced gradient of decline in mangrove biodiversity and tree height northwards in the South China Sea province. This is due mainly to a reduction in the average ambient temperature with latitude. The mangroves in Hainan (Latitude 18–20°N) include 35 plant species comprising of 26 native true mangrove and nine mangrove-associate species (Wang *et al.*, 2020; Chen *et al.*, 2021). In contrast, there are only nine mangrove species in China's Fujian Province (23.5° N - 27° N), eight mangrove species in Hong Kong (22.4° N) and six species in Taiwan (22° N - 25° N), including two species that are locally extinct (Wester and Lee, 1992; Li and Lee, 1997; Tam and Wong, 2002). At these northern latitudes the growth of mangroves is also stunted and most trees are dwarf-like in stature.

The mangroves in this northerly province of Southeast Asia are characterised by cold-adapted *Kandelia* trees. The species in northern Viet Nam is *K. candel*, while *K. obovata* was recently identified as a second species in China (Sheue *et al.,* 2003). *Kandelia* mangroves are also abundant in this province because they are commonly planted for mangrove rehabilitation and afforestation purposes. Other cold-tolerant species in China include *Avicennia marina*, which is common at low intertidal levels in high salinity areas; and *Bruguiera gymnorhiza*, which is a dominant species at high intertidal levels (Wang *et al.,* 2020).

Abiotic components of the ecosystem

Mangrove distribution in the South China Sea province is influenced strongly by interactions among landscape position, temperature, rainfall, hydrology, sea-level, sediment dynamics, shore subsidence and storm-driven processes (Hong and San, 1993; Hsueh and Lee, 2000). 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.

Mangroves are tropical, subtropical and warm temperate forest communities that are limited by average temperatures below 25ºC and cold temperature shocks below 15ºC. The South China Sea province has a subtropical monsoon climate with a distinctly colder winter season. For example, the average January temperature in Fujian Province (the northern limit of mangroves in mainland China) is 4.9 °C, but in Fujian and Hong Kong winter lows can reach almost zero. Thus, low temperature with frequent chilling events is the main abiotic factor limiting mangrove distribution and diversity at these northern latitudes (Chen *et al.,* 2017).

A lack of fine sediments and nutrients are secondary factors suppressing mangrove colonisation and growth in many locations within the South China Sea province. Except for the deposition of fine alluvium within the Red River Delta, storms and wave action along the more exposed coastlines of this province carry fine-grained sediments and nutrients offshore. This is a further reason why the mangrove trees are smaller and less diverse compared to the tropical provinces of Southeast Asia. Some mangrove stands in Hong Kong, for example, are limited in extent and growth form by the presence of shallow sandy and stony soils with poor structure (Tam and Wong, 2002).

Key processes and interactions

Mangroves are structural engineers and possess traits, including pneumatophores, salt excretion glands, vivipary and buoyant propagules, that promote recruitment and survival in poorly aerated, saline, mobile and tidally inundated substrata. 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 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 microhabitats for other invertebrates.

Specialised mangrove roots (pneumatophores and aerial prop roots) provide important temporary habitats that protect juvenile fish from predators during high tides. They also serve as permanent habitat for the attachment of algae and sessile invertebrates (e.g., barnacles, oysters, mussels), as well as refuges for crabs and gastropods. Many of these mangrove-associated aquatic species are an important source of food and income for coastal households in northern Viet Nam and China. The mangrove vegetation provides habitat for numerous terrestrial invertebrate herbivores, especially insects, as well as small mammals, reptiles, and a diverse bird fauna.

Mangrove ecosystems are also major blue carbon sinks, incorporating organic matter into sediments and living biomass. Due to lower temperatures and other factors constraining the growth potential of mangroves in the South China Sea province, mangrove above ground carbon sequestration and storage are lower than in tropical mangrove ecosystems (Estrada and Soares, 2017). Moreover, the rate of carbon sequestration by mangrove vegetation in China has declined by more than 10% in recent years despite the gain in mangrove cover resulting from improved protection and large-scale mangrove rehabilitation (Wang *et al.*, 2020). The estimates of below ground carbon sequestration and storage are also low, reflecting the fact that much of the mangrove extent in the South China Sea province comprises of plantations established for reforestation or afforestation purposes, rather than mature forest ecosystems. In young mangrove forest plantations studied in China, soil carbon storage was found to increase significantly with forest age (Lunstrum and Chen, 2014). The average carbon content in mangrove soils (to one metre depth) in the four most northern provinces of Viet Nam was reported to be only 78 to 121 Mg C ha-1 (Pham *et al.*, 2020). For comparison, much higher soil carbon values of 229 and 378 Mg C ha-1 are present in replanted fringe and interior mangroves, respectively, in the Mekong Delta of southern Viet Nam in the Sunda Shelf province (Nam *et al.*, 2016).

3. Ecosystem Threats and Vulnerabilities

Main threatening process and pathways to degradation

Mangrove degradation often begins with over-harvesting of wood and aquatic products, followed by encroachment and pollution from nearby urban, industrial or other coastal development activities. In some locations mangroves are threated directly by large-scale conversion for agriculture, aquaculture or coastal infrastructure projects, especially sea dyke construction for coastal land reclamation and storm surge protection. The position of mangrove forests in intertidal areas also renders them vulnerable to predicted sea-level rise due to climate change. Typhoons and storm surges in the South China Sea province can damage mangrove forests through direct defoliation and destruction of vegetation, as well as by impacting on mangrove-associated animal communities. Previously, coastal land reclamation, agriculture, aquaculture and associated coastal infrastructure development were the major threats to mangroves in mainland China, Hong Kong and Taiwan (Li and Lee, 1997; Fan, 2002; Tam and Wong, 2002). In Taiwan impacts from coastal development activities are blamed for the local extinction of two mangrove species, while land subsidence caused by extracting groundwater for aquaculture led to flooding in mangrove habitats and the death of trees (Fan, 2002).

Coastal aquaculture ponds converted from mangrove habitat in Thai Thuy District, Thai Binh Province in the Red River Delta region of Viet Nam (Photo credit: Pham Hong Tinh).

Mangrove conversion for agriculture or aquaculture, and land reclamation, are no longer the major causes of mangrove loss in mainland China, Hong Kong and Taiwan. Coastal land reclamation projects have been forbidden in mainland China since 2018 and seawall construction is now considered to be the root cause of mangrove degradation (Wang *et al.*, 2020). Although the remaining mangroves in these countries and territories are conservation priority, with many stands assigned to designated nature reserves, the mangrove habitat areas are quite small and scattered, making their protection from degradation more challenging (Tam and Wong, 2000; Wang *et al.*, 2020). The extensive mangroves in the Red River Delta of northern Viet Nam have been degraded by intense human activity, including wood harvesting, aquatic harvesting (gleaning), fishing and, as in China, by sea dyke construction. There has also been large-scale mangrove conversion for agricultural and aquacultural use and, more recently, for coastal urban or industrial development (Le *et al.*, 2020).

Another threat to mangroves in this province, especially in densely planted mangrove rehabilitation sites, are pests and predators. They include barnacles and algae that attach to, then weigh down and topple mangrove seedlings; herbivorous caterpillars that defoliate trees; wood-borers; invasive plants and even fish (Fan, 2002; Fan and Qiu, 2004). As the large human population in this province continues to increase, coastal cities and their economies are expanding, which is threatening even well-protected mangroves, both directly through land development pressures and indirectly through pollution risks and disturbances, including from tourism activities. Shenzhen Futian Nature Reserve near Shenzhen City is a good example of a designated mangrove protected area in China that is adjacent to a large urban centre, while mangroves in Xuan Thuy National Park (part of the Red River Delta Biosphere Reserve) are threatened by degradation from over-harvesting of aquatic resources and conversion to aquaculture. 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 provided sediment flows are sufficient for mangrove development to keep pace with sea-level rise (Schuerch *et al.*, 2018).

The coastal landscape of Zhangjiang Estuary, Fujian Province, China. Invasive grass (Spartina alterniflora) occupies the seaward edge of the mangroves, with fish ponds on the landward side (Photo credit: Hongyu Feng).

Protected mangroves adjacent to Shenzhen City in Guangdong Province, China (Photo credit: Haichao Zhou).

Definition of the collapsed stated of the ecosystem.

Mangroves are structural engineers and possess specialised traits that promote high nitrogen use efficiency and nutrient resorption that influence major processes and functions in coastal ecosystems. Mangroves are also highly dynamic systems, with species distributions adjusting to local changes in tidal and freshwater regimes that determine inundation characteristics, sediment distribution, salinity gradients and water quality. Processes 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 addition to the significant loss of mangrove forest area in China, 50% of the 26 true mangrove species recorded there are under threat of local extinctions, especially species that occupy the middle and high intertidal levels. Forest structure and the rate of carbon sequestration have also declined (Wang *et al.*, 2020). Large scale conversion of mangroves to agriculture and aquaculture in northern Viet Nam has been offset to some extent by mangrove afforestation activities made possible by the rapid rate of nutrient-rich sediment deposition and shoreline accretion in the Red River Delta. However, there is also pressure to convert planted mangroves into aquaculture ponds, while hydropower dams on this river system are reducing the delivery of sediments and nutrients to the coast (Le *et al.,* 2020). Loss of mangrove cover and reduced sediment deposition in northern Viet Nam could lead to ecosystem collapse caused by typhoons and wave surges, while sea-level rise represents a further threat caused by climate change.

Threat Classification

IUCN Threat classification (version 3.3, IUCN 2022) relevant to the South China Sea 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
- 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 Waste Water
  - 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
- 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 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 and the estimated figures for 1970 should be considered only indicative (see appendix for further details of the methods and limitations).

In contrast, to estimate the South China Sea mangrove area from 1996 to 2020, we used the most recent version of the Global Mangrove Watch (GMW v3.0) spatial dataset. The mangrove area in the province (and in the countries within) was corrected for both omission and commission errors, utilizing the equations in Bunting *et al.* (2022).

The South China Sea	2020*	1970*	Net area Change (Km^2)	% Net Area Change	Rate of change (%/year)
	542	844	302	-35.8%	-0.72%

**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 (Annex 3. Table a) show that the South China Sea province lost approximately 36% of its mangrove area over the past 50 years (1970-2020). China and Viet Nam lost more than 33% and 36% of their mangrove area in this period, respectively. Given that the change in geographic distribution is above the 30% risk threshold, but below 50%, the 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 South China Sea province mangroves show a net area loss of ≈ 4% (1996-2020) based on the GMW v3.0 dataset (Bunting *et al.*, 2022). This value reflects the offset between areas gained (0.42%/year) and lost (0.6%/year). The largest decline in mangrove area occurred between 1996 and 2007; but since 2008 then there has been a deceleration in net area loss. As there is no clear trend (neither linear nor exponential), it is not possible to use a regression ($R^2 < 0.3$) to predict the mangrove area over the next 50 years. Therefore, the South China Sea mangrove ecosystem is assessed as **Data Deficient (DD)** under subcriteria A2a and A2b.

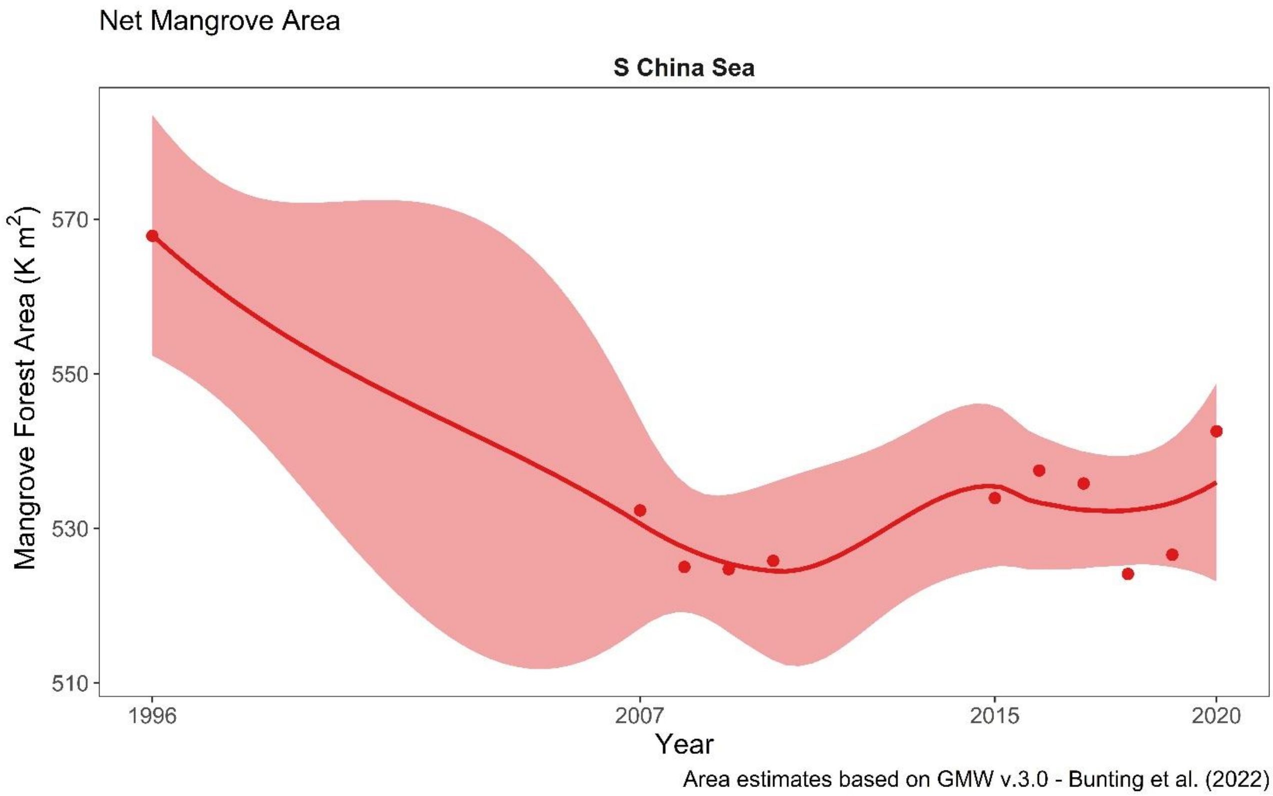


Figure 1. South China Sea province mangrove area between 1996 and 2020. Estimates based on GMW v3.0 (Bunting *et al.*, 2022). The solid line and shaded area are the loess regression and 95% confidence intervals.

Subcriterion A3 measures change in mangrove area since 1750. Unfortunately, there are no reliable data on mangrove extent for the entire province during this period, and therefore the South China Sea 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

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
South China Sea	865,568	108	LC

For 2020, AOO and EOO in the South China Sea province were measured as 281 grid cells 10 x 10 km and 865,568 km^2 respectively (figure 2), based on the GMW v3.0 dataset. Excluding from the AOO those grid cells that contain patches of mangrove forest that account for less than 1% of the grid cell area, (< 1 km2), the AOO is measured as 108, 10 x 10 km grid cells (Figure 3, purple grids).

Considering the very high number of threat-defined-locations, there is no evidence of plausible catastrophic threats leading to potential disappearance of mangroves across their extent.

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

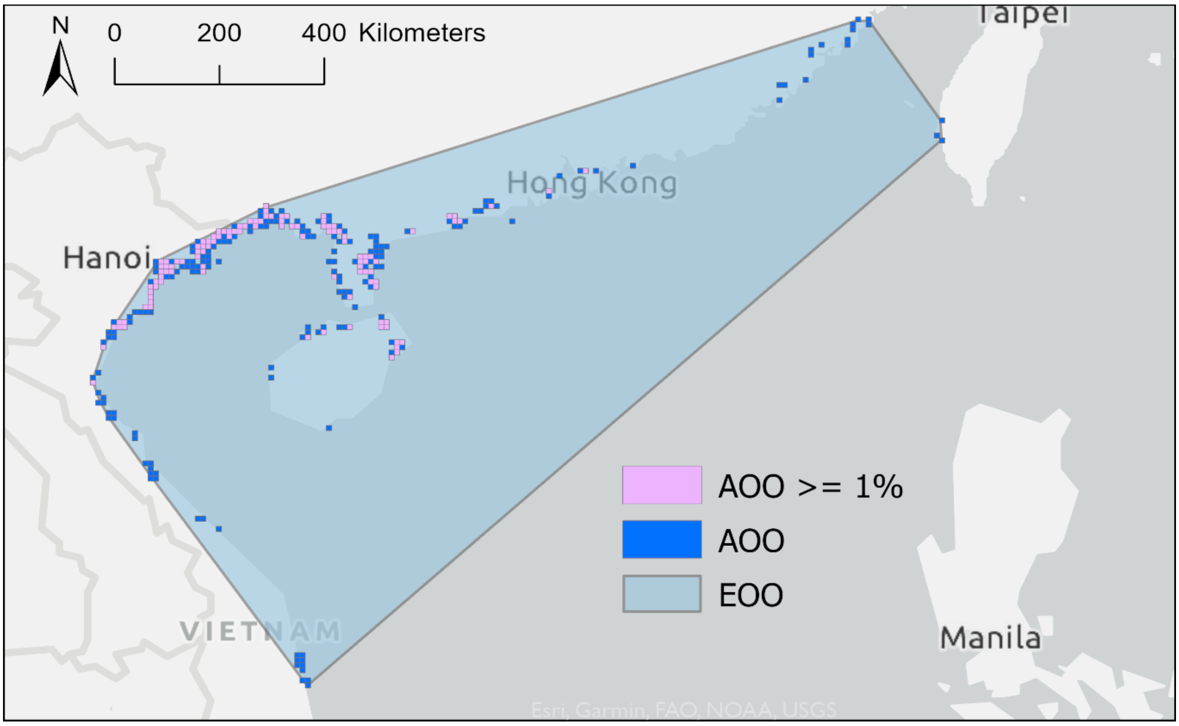


Figure 2. 2020 South China Sea mangrove Extent Of Occurrence (EOO) and Area Of Occupancy (AOO). Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022). The pink 10 x 10 km grids are more than 1% covered by the ecosystem (n = 108), and the blue grids <1% (n = 173).

Criterion C: Environmental Degradation

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

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

Subcriterion C2 measures environmental degradation in the future, or over any period of 50 years, 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 South China Sea 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.

Using this model and considering a plausible mid-high SLR scenario (IPCC RCP6, 0.45 m SLR by 2100), ≈50% of the South China Sea mangrove forest would be submerged by 2070 (figure 3). Considering that no mangrove recruitment can occur in a submerged system (100% relative severity), and 50% of the ecosystem extent will be affected by SLR, the South China Sea mangrove ecosystem is assessed as **Endangered (EN)** for subcriterion C2.

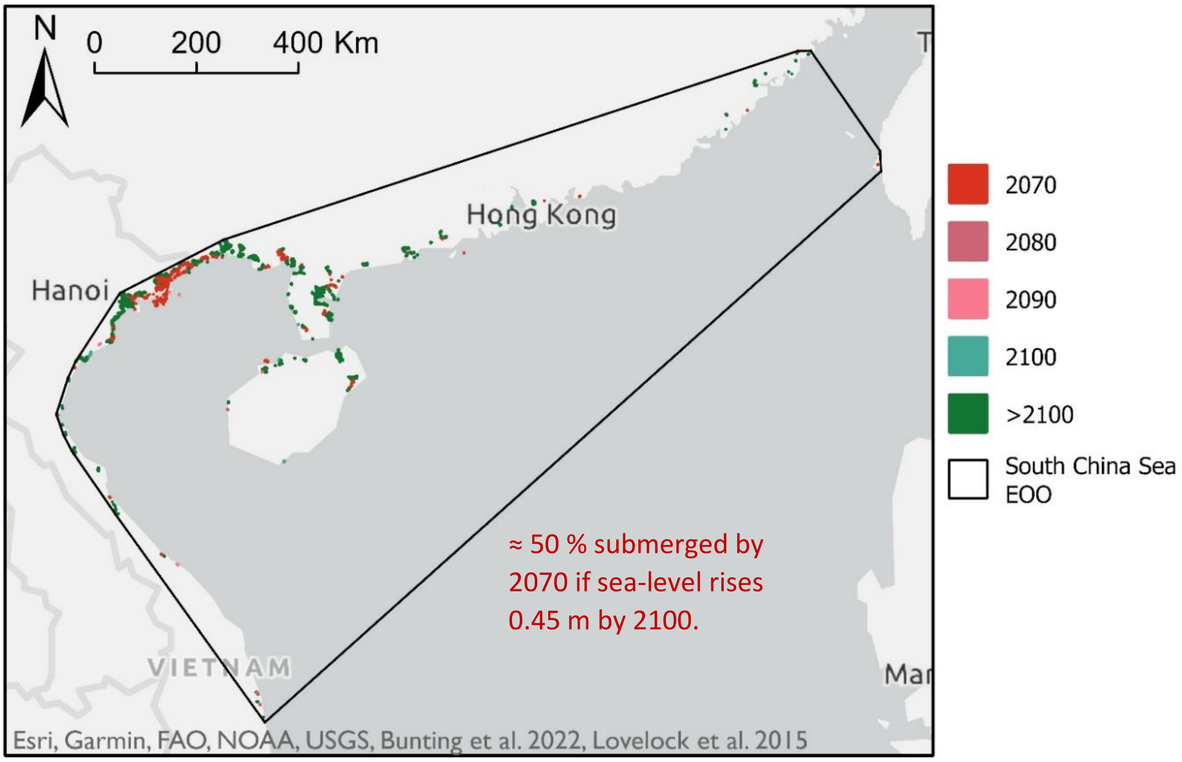


Figure 3. South China Sea mangrove forest predicted decade of submerge under IPCC RCP 6 scenario (0.45 m Global SLR by 2100), based on the model of Lovelock *et al.* (2015). Mangrove extent based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022).

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

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

Criterion D: Disruption of Biotic Processes or Interactions

The global mangrove degradation map developed by Worthington and Spalding (2018) was used to assess the level of biotic degradation in the South China Sea 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 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), 3.5% of the South China Sea mangrove area has degraded, resulting in an average annual rate of degradation of 0.2%. Assuming that this trend remains constant, +10.2% of the South China Sea's mangrove area will be classified as degraded over a 50-year period. Because less than 50% of the ecosystem will meet the category thresholds for criterion D, the mangroves are assessed as **Least Concern (LC)** under subcriterion D2b.

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

Overall, the South China Sea 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)
	VU	**DD**	**DD**
B. Restricted Geo. Distribution	**B1** Extent of Occurrence	**B2** Area of Occupancy	**B3** # Threat-defined Locations < 5?
	LC	**LC**	**LC**
C. Environmental Degradation	**C1** Past 50 years (1970)	**C2** Future or Any 50y period	**C3** Historical (1750)
	DD	**EN**	**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	**EN**		

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

Overall, the status of the South China Sea mangrove ecosystem is assessed as **Endangered (EN).**

6. References

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Authors:

Macintosh, D. J., Suárez, E.L., Chen, L., Pham, H.T., Nightingale, M., & Valderrábano, M.

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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	Fabales	Fabaceae	*Cynometra iripa*	LC
Magnoliopsida	Gentianales	Rubiaceae	*Scyphiphora hydrophylacea*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Acanthus ilicifolius*	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	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 tagal*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Ceriops zippeliana*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Kandelia candel*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Kandelia obovata*	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	*Camptostemon philippinensis*	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 ovata*	NT
Magnoliopsida	Myrtales	Myrtaceae	*Osbornia octodonta*	LC
Magnoliopsida	Ericales	Primulaceae	*Aegiceras corniculatum*	LC
Magnoliopsida	Ericales	Primulaceae	*Aegiceras floridum*	NT
Magnoliopsida	Sapindales	Meliaceae	*Aglaia cucullata*	DD
Magnoliopsida	Sapindales	Meliaceae	*Xylocarpus granatum*	LC
Magnoliopsida	Sapindales	Meliaceae	*Xylocarpus moluccensis*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Acanthus ebracteatus*	LC
Magnoliopsida	Lamiales	Acanthaceae	*Acanthus volubilis*	LC
Polypodiopsida	Polypodiales	Pteridaceae	*Acrostichum aureum*	LC

Class	Order	Family	Scientific name	RLTS category
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
Magnoliopsida	Fabales	Fabaceae	*Cynometra ramiflora*	LC	
Actinopterygii	Albuliformes	Albulidae	*Albula glossodonta*	VU	Shortjaw bonefish
Actinopterygii	Albuliformes	Albulidae	*Albula vulpes*	NT	Bonefish
Actinopterygii	Clupeiformes	Clupeidae	*Sardinella melanura*	LC	Blacktip sardinella
Actinopterygii	Clupeiformes	Engraulidae	*Encrasicholina punctifer*	LC	Buccaneer anchovy
Actinopterygii	Clupeiformes	Engraulidae	*Stolephorus andhraensis*	LC	Andhra anchovy
Actinopterygii	Clupeiformes	Engraulidae	*Thryssa kammalensis*	DD	[Kammal thryssa]
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	*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
Actinopterygii	Gobiiformes	Gobiidae	*Mugilogobius cavifrons*	LC	Bandfin mangrove goby
Actinopterygii	Gobiiformes	Gobiidae	*Oligolepis stomias*	DD	Plain teardrop goby
Actinopterygii	Gobiiformes	Gobiidae	*Parachaeturichthys polynema*	LC	Lancet-tail goby
Actinopterygii	Gobiiformes	Gobiidae	*Paratrypauchen microcephalus*	LC	Comb goby
Actinopterygii	Gobiiformes	Gobiidae	*Taenioides cirratus*	DD	Whiskered eel 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	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	Haemulidae	*Plectorhinchus pictus*	LC	Trout sweetlips
Actinopterygii	Perciformes	Leiognathidae	*Leiognathus equulus*	LC	Common ponyfish
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus harak*	LC	Thumbprint emperor

Class	Order	Family	Scientific name	RLTS category	Common name
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	Sciaenidae	*Johnius australis*	LC	Bottlenose jewfish
Actinopterygii	Perciformes	Sciaenidae	*Johnius carouna*	LC	Caroun croaker
Actinopterygii	Perciformes	Siganidae	*Siganus guttatus*	LC	Golden rabbitfish
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron manilensis*	LC	Narrow-lined puffer
Aves	Ciconiiformes	Ciconiidae	*Leptoptilos javanicus*	VU	Lesser adjutant
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	*Todiramphus chloris*	LC	Collared kingfisher
Aves	Passeriformes	Aegithinidae	*Aegithina tiphia*	LC	Common iora
Aves	Passeriformes	Pachycephalidae	*Pachycephala cinerea*	LC	Mangrove whistler
Aves	Suliformes	Anhingidae	*Anhinga melanogaster*	NT	Oriental darter
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis pectinata*	CR	Smalltooth sawfish
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	Stylommatophora	Achatinellidae	*Lamellidea pusilla*	LC	
Mammalia	Carnivora	Felidae	*Panthera pardus ssp. delacouri*	CR	Indochinese leopard
Mammalia	Cetartiodactyla	Phocoenidae	*Neophocaena phocaenoides*	VU	Indo-pacific finless porpoise
Reptilia	Squamata	Elapidae	*Bungarus fasciatus*	LC	Banded krait
Reptilia	Squamata	Pythonidae	*Python bivittatus*	VU	Burmese python

3. National Estimates for Subriterion A1

To estimate the South China Sea mangrove ecosystem extent in 1970, we gathered reliable information on the mangrove area for each country within the province around this period (Table b). We then estimated the mangrove area in 1970 for each country, assuming a linear relationship between mangrove extent and time. Finally, we summed up the country estimates to determine the total mangrove area in the South China Sea 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	Within province 2020*	Within province 1970**
China	212.2	315
Taiwan	0.1	
Viet Nam	330.3	529
South China Sea	542.6	844

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

Country	Year	Mangrove Area (Ha)	Reference
China	1956	42,001	Forest resources survey (1956): China Ocean 21st Century agenda action plan 1996.
China	1986	17,035	Coastal vegetation survey (1986): China Ocean 21st Century agenda action plan 1996.
China	1986	21,283	Coastal forest survey (1986): China Ocean 21st Century agenda action plan 1996.
China	1988	23,000	Coastal topography survey (1988): Chen, J.Y., & Huang, J.S. (1995) Chinese coastal landscape. Ocean Press, Beijing.
Viet Nam	1971	295,877	FAO, UNEP (1981). Tropical Forest Resources Assessment Project, Forest Resources of Tropical Asia FAO, UNEP, 475 pp
Viet Nam	1965	320,000	Granich, S., Kelly, M., & Ninh, N.H. (1993). Global Warming and Viet Nam. A briefing document. University of East Anglia, Norwich, UK, International Institute for Environment and Development, London, UK, Centre for Environment Research Education and Development, Hanoi, Viet Nam. http://www.cru.uea.ac.uk/tiempo/floor0/briefing/vietnam/index.htm#section2
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.