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Mangroves of the Warm Temperate Northwest Pacific

LC

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Abstract
Mangroves of the Warm Temperate Northwest Pacific is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology). It includes intertidal forests and shrublands of the marine ecoregions of the East China Sea, that extend across China, Taiwan and South Korea. The Warm Temperate Northwest Pacific mangrove province mapped extent in 2023 was 6.83 km^2, representing 0.0038% of the global mangrove area.

This ecoregion is characterised by four species of true mangroves, plus many associated taxa. *Kandalia obovata* is the dominant mangrove species, while *Avicennia marina*, *Aegiceras corniculatum*, and *Excoecaria agallocha* are only observed sparsely. The Warm Temperate Northwest Pacific mangroves are mainly scattered estuarine formations.

Today the Warm Temperate Northwest Pacific mangroves cover 93% more area than our broad estimation for 1970. The mangrove area of Taiwan has increased by 253% since 1976. The mangrove area of Zhejiang, China has increased 48 times since 1957. Furthermore, under a high sea-level rise scenario (IPCC RCP 8.5) ≈-0.4% of the Warm Temperate Northwest Pacific mangroves would be submerged by 2060. Moreover, 18.2% of the province's mangrove ecosystem is undergoing degradation, with the potential to increase to 42.8% within a 50-year period, based on a vegetation index decay analysis. Overall, the Warm Temperate Northwest Pacific mangrove ecosystem is assessed as **Least Concern (LC)**

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

Ecosystem classification:
MFT1.2 Intertidal forests and shrublands
Assessment's distribution:
Warm Temperate Northwest Pacific 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 Warm Temperate Northwest Pacific

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_09 Mangroves of the Warm Temperate Northwest Pacific

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

1 Forest

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

12 Marine Intertidal

12.7 Mangrove Submerged Roots

Mangroves in Zhuwei, New Taipei City, Taiwan
(Photo credit: Hsing-Juh Lin).

Mangroves in Xinfeng, Hsinchu County, Taiwan
(Photo credit: Hsing-Juh Lin).

Mangrovs in Ximen Island, the north most region for mangroves in China (Photo credit: Yining Chen)

2. Ecosystem Description

Spatial distribution

Mangroves of the Warm Temperate Northwest Pacific includes intertidal forest and shrublands of the marine ecoregions of East China Sea, that extend across China, Taiwan and South Korea (Figure 1). This province includes the south-eastern coast of China, the northern and eastern coast of Taiwan and the southern coast of South Korea (Spalding *et al.,* 2007). Based on the typology of Worthington *et al.,* (2020), the mangroves of this province are mainly estuarine formations. Some mangroves in Taiwan are restricted to the sheltered coast.

There are no mangroves on the exposed eastern Pacific Ocean-facing coastline and the exposed northern East China Sea-facing coastline of Taiwan because it is steep and most of the coast is rocky shore (Lin *et al.*, 2023a).

Mangroves in Maoyan Island, Zhejiang Province (Photo credit: Yining Chen

The estimated extent of mangroves in this province is 6.83 km^2 in 2023, representing about 0.0038% of the global mangrove area. The mangrove area on the north-western coast of Taiwan has increased by 270% from 53.7 ha in 1976 to 198.8 ha in 2023 due to the protection given to most mangroves (Lin *et al*. 2023a). The increase in mangrove area in Taiwan has been caused mainly by mangrove planting and its subsequent expansion. Overgrown mangroves may lead to mosquito breeding and flooding (Shih *et al*., 2015) and even lead to reduction in pre tree carbon sequestration (Ho *et al*., 2018), biodiversity (Pan *et al*., 2021), and greenhouse gas emissions (Lin *et al*., 2020). However, overall, there has been a -24.2 % net area change in the mangroves of the Warm Temperate Northwest Pacific since 1996 (Bunting *et al.,* 2022).

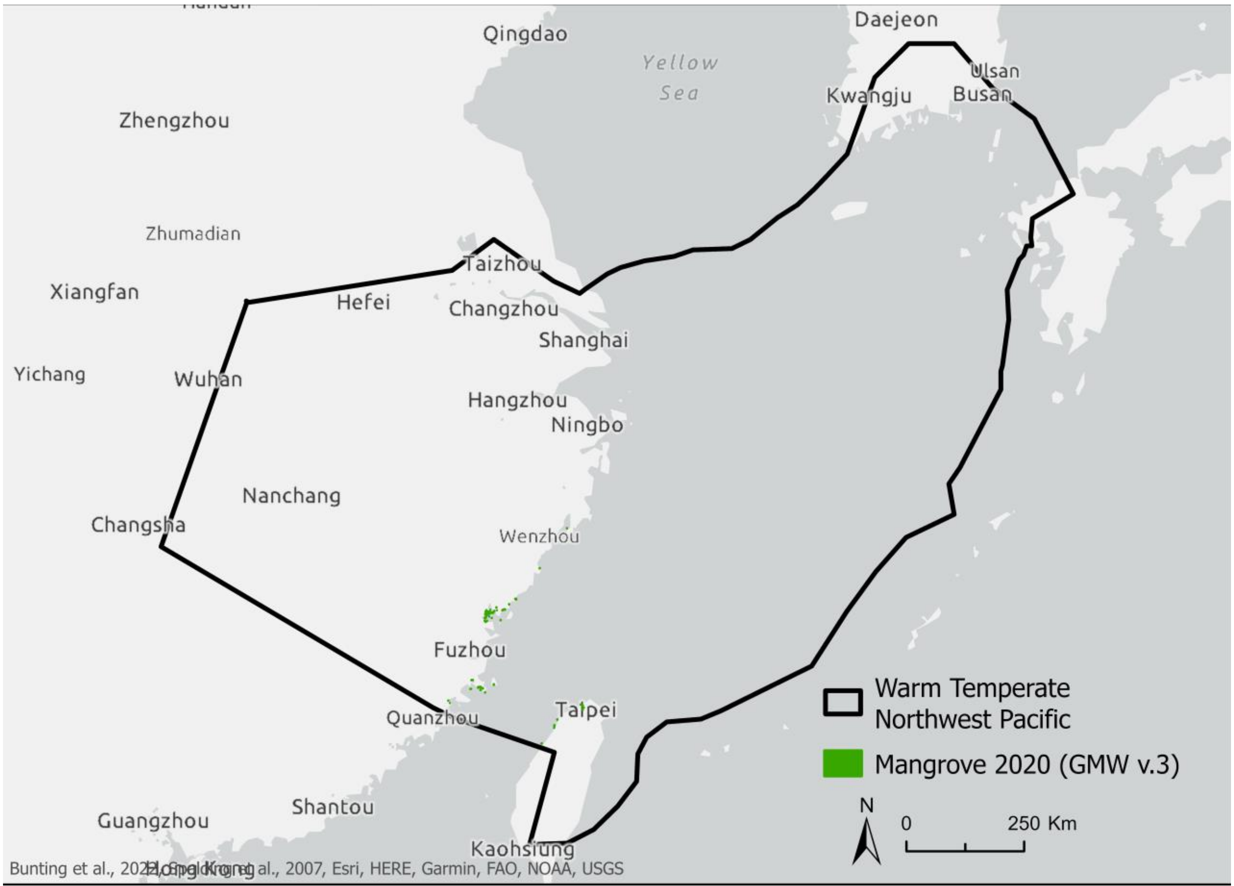

Figure 1. The mangroves of Warm Temperate Northwest Pacific.

Although the natural northern boundary of mangroves in China is restricted to a latitude of 27◦20′ N (north Fujian Province), *Kandelia obovata* has been planted successfully on the southern coasts of Zhejiang. In 1957, 122 *Kandelia obovata* plants, originating from Fujian Province, were planted on the tidal flats at Zhejiang (Qiu *et al*., 2010). Ximen Island, Wenzhou, at a latitude of 28◦20′ N, has become the northernmost location for mangrove forests in China since 1957 (Chen *et al*., 2023). Initially, the planted mangroves appeared mainly on the tidal flats of Wenzhou, but their distribution then extended to Taizhou from 2002. The extent of the planted mangrove forests in Zhejiang increased over many years from the 1950s and the. cumulative area of mangrove forest plantation reached a maximum of 1700 ha (Chen *et al*., 2015). However, this number declined to less than 20 ha in the 1990s, due to human disturbance and natural threats (Chen *et al*., 2015, 2017, 2023). Since the 2000s, many attempts have been made by local communities to protect and reforest mangrove forests in Zhejiang and at present the total area is 484 ha (Department of Forestry of Zhejiang Province, 2023).

Biotic components of the ecosystem (characteristic native biota)

The mangroves of the Warm Temperate Northwest Pacific province are limited to four true mangrove plant species (IUCN, 2022). *Kandelia obovata* is the species dominating the mangrove forests in this province, while the other three species, *Avicennia marina*, *Aegiceras corniculatum*, and *Excoecaria agallocha* are only observed sparsely. Meanwhile, *Myoporum bontioides* is the main mangrove-associated species in Zhejiang (Chen *et al.*, 2015). Generally, no understory layer develops within these reforested mangroves. The north-western mangrove trees of Taiwan are relatively short, averaging 3.4 – 5.1 m high (Lin *et al*., 2023b), but the tree density is high, reaching 2.19 stem m^{-2} (Li *et al*., 2018).

The mangroves on the north-western coast of Taiwan provide diverse and ecologically significant habitats. They are inhabited by a wide variety of species across different taxonomic groups. *Phragmites communis* is the associated marshland vegetation in the mangroves (Lin *et al*., 2003). In total, 556 insect species belonging to 120 families were collected in the mangroves. With *Chironomus* sp., *Culicoidini* sp. and *Cricotopus sylvestris* being the most frequently observed insect species (Lin *et al*., 2003; Maa *et al.*, 2006). The macrobenthos species include Chordata, Cnidaria, Annelida, Sipuncula, Mollusca and Arthropoda (Pan *et al.*, 2021). In total, 43 molluscan species belonging to 19 families were collected in the mangroves, in which *Thiara riqueti*, *T. tuberculata*, and *Assiminea* sp. are the dominant species (Lin *et al*., 2003). In total, 50 fish species were caught in the mangrove creeks (Kuo *et al*., 1999). *Liza macrolepis*, *Liza affinis*, *Acentrogobius viridipunctatus*, *Acanthopagrus schlegeli*, *Terapon jarbua*, *Leiognathus nuchalis* and *Oreochromis* hybrids are the dominant fish species. Among them, 51% and 30% of the fish species are marine migrants and estuarine species. The individual number was highly correlated with soil organic content. In total, 119 bird species were observed in the mangroves. The bird communities were dominant in number by *Anas crecca*, *Bubulcus ibis*, and *Ardea cinerea* (Lin *et al*., 2003).

A total of 69 species of macrobenthos were collected from a reforested mangrove forest in Taizhou, and the species richness was dominated by gastropoda (23 species), polychaeta (18 species), and malacostraca (16 species) (Wang *et al*., 2020). In contrast, 17 taxa of the macrobenthos were identified in the mangrove of Ximen Island, with dominant species of *Phascolosoma esculenta*, *Assiminea brevicula* and *Alpheus distinguendus* (Liao *et al.*, 2020). In a restored mangrove forest in south Wenzhou, 88 species of birds were observed, dominated in number by *Calidris alpina*, *Egretta garzetta*, *Calidris ruficollis* and *Charadrius alexandrinus* (Han *et al*., 2020).

Abiotic Components of the Ecosystem

The soils of the north-western mangroves of Taiwan are mainly silt in texture and the organic matter content averages 4.7% (Lin *et al*., 2023b). Regional distributions are influenced by interactions among landscape position, rainfall, hydrology, sea level, sediment dynamics, subsidence, storm-driven processes, and disturbance by pests and predators. Rainfall and sediment supply from rivers and currents promote mangrove establishment and persistence, while waves and large tidal currents destabilise and erode mangrove substrata, mediating local-scale dynamics in ecosystem distributions. High rainfall reduces salinity stress and increases nutrient loading from adjacent catchments, while tidal flushing also regulates salinity.

Key processes and interactions

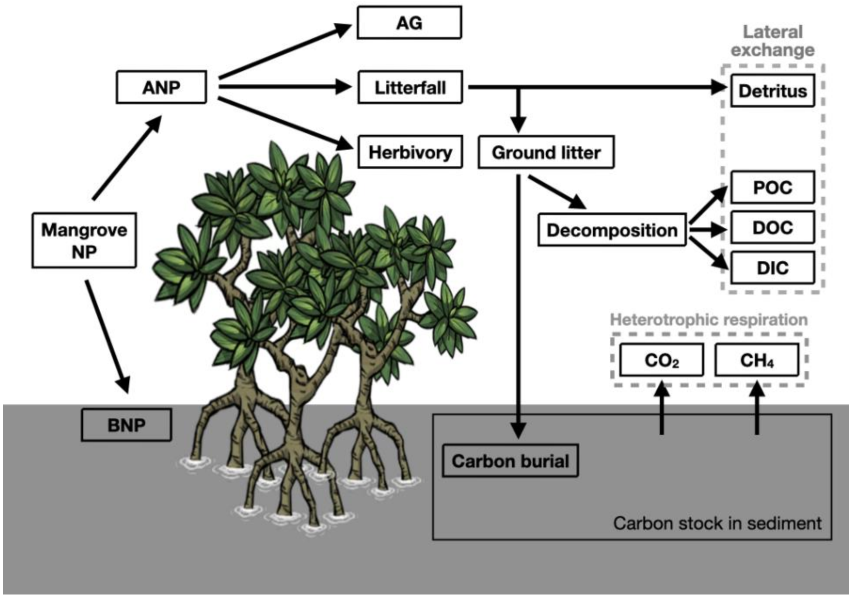

Fig. 2. The conceptual model of the mangrove carbon budget. NP: net production; ANP: aboveground net production; BNP: belowground net production; AG: aboveground growth; POC: particulate organic carbon; DOC: dissolved organic carbon; DIC: dissolved organic carbon. (Lin *et al*., 2023b)

Mangroves act as structural engineers possessing traits such as pneumatophores, salt excretion glands, vivipary, and propagule buoyancy that promote survival and recruitment in poorly aerated, saline, mobile, and tidally inundated substrata. They exhibit high efficiency in nitrogen use and nutrient resorption. Mangroves produce large amounts of detritus (e.g., leaves, twigs, and bark), which is either buried in waterlogged sediments, consumed by crabs and gastropods, or more commonly decomposed by fungi and bacteria, thus mobilising carbon, and nutrients to higher trophic levels.

Mangroves also serve as major blue carbon sinks, incorporating organic matter into sediments and living biomass. While the aboveground portion of *K. obovata* contributed 44% of the total carbon stock, the non-fine roots accounted for 17% of the total carbon stock and the fine roots and dead fine roots contributed the other 5% (Chou *et al*., 2022). The soil carbon stock (194 Mg C ha^{-1}) of *K. obovata* is much higher than the tree carbon stock (63 Mg C ha^{-1}) (Lin *et al.*, 2023a). The mangrove net production (NP) of *K. obovata* is higher than the global average for mangroves, which can be attributed to the high tree density (Li *et al.*, 2018). The NP of *K. obovata* ranged from 24.62~41.23 Mg C ha^{-1} yr^{-1}, which is higher than that of the dominant mangrove species (*A. marina*) in southern Taiwan (7.08~15.67 Mg C ha^{-1} yr^{-1}) (Lin *et al.*, 2023b). An additional 13.67 Mg C ha^{-1} yr^{-1} derived from the fine root production of *K. obovata* contributes to soil carbon burial, which can increase the carbon sequestration capacity of *K. obovata* by five times (Chou *et al*., 2022). The carbon budgets for *K. obovata* mangroves in northern Taiwan (Fig. 2) show that the aboveground net production (ANP) contributed, on average, 76.4% of the mangrove NP, of which 72.5% was derived from aboveground growth, whereas 27.5% was derived from litterfall production (Li *et al*., 2018). A small proportion of litterfall (16.0%) was exported via tidal currents, suggesting that high proportions of litterfall remained on the soil. The decomposition rates of the ground litter were fast, as 82.2% of the ground litter decomposed within one year. CO_2 and CH_4 fluxes across the soil–air interface were 6.09 ± 3.16 and 0.02 ± 0.02 Mg C ha^{-1} yr^{-1}, respectively. Mangrove-derived carbon burial in the carbon budgets ranged from 0.25~1.55 Mg C ha^{-1} yr^{-1} for *K. obovata* mangroves. The carbon burial was only 3.0% ± 1.6% of the NP or 15.2% ± 8.1% of the litterfall for *K. obovata*. Wind speed is correlated highly with litterfall and soil carbon burial, indicating that wind speed is the main factor regulating carbon burial in *K. obovata* mangroves in northern Taiwan (Lin *et al.*, 2023b). Some mangroves may grow in environments with lower salinity, so soil microorganisms will produce methane from soils rich in organic carbon, which may offset the carbon sequestration capacity (Lin *et al*., 2020).

3. Ecosystem Threats and vulnerabilities

Main threatening process and pathways to degradation

Mangrove deforestation arises from various factors, including aquaculture, urbanization, associated coastal development, over-harvesting, and pollution stemming from domestic, industrial, and agricultural land use. The location of mangrove forests within intertidal areas renders them vulnerable to predicted sea-level rise as a result of climate change. Tropical storms can damage mangrove forests through direct defoliation and destruction of trees, as well as through the mass mortality of animal communities within the ecosystems. In Taiwan, thinning or deforestation has been proposed as a managerial action for some overgrown mangroves, which could decrease biodiversity and increase flooding risks (Shih *et al.*, 2015). Medium thinning appears to be the optimal strategy to meet the need to reduce the loss of carbon sequestration capacity in mangrove management (Ho *et al.*, 2017). To maximize carbon sequestration, managing the density to 30,600 trees ha^{-1} for *K. obovata* has been suggested. In Zhejiang, human disturbance (e.g., reclamation and aquaculture) and natural threats (e.g., cold waves and pests) have resulted in the decline of mangrove area to 20 ha in 1990s (Chen *et al*., 2015, 2017, 2023).

Deforestation has been proposed as a managerial action for some overgrown mangroves which could decrease biodiversity and increase flooding risks (*Photo credit: Hsing-Juh Lin)*

Definition of the collapsed state of the ecosystem

Mangroves, acting as structural engineers, possess specialized traits that facilitate high nitrogen use efficiency and nutrient resorption, influencing critical processes and functions within their ecosystem. Ecosystem collapse is recognized when the tree cover of diagnostic true mangrove species dwindles to zero, indicating complete loss (100%). These ecosystems exhibit remarkable dynamism, with species distributions adapting to local shifts in sediment distribution, tidal patterns, and variations in local inundation and salinity gradients. Disruptive processes can trigger shifts in this dynamism, potentially leading to ecosystem collapse. Ecosystem collapse may manifest through the following mechanisms: a) restricted recruitment and survival of diagnostic true mangroves due to adverse climatic conditions (e.g., low temperatures); b) alterations in rainfall, river inputs, waves, and tidal currents that destabilize and erode soft substrata, hindering recruitment and growth; c) shifts in rainfall patterns and tidal flushing altering salinity regimes and nutrient loading, thereby impacting overall survival.

Threat Classification

IUCN Threat Classification (version 3.3, IUCN-CMP, 2022) relevant to mangroves of the Warm Temperate Northwest Pacific 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
- 4.4 Flight paths

5. Biological resource use

- 5.1 Hunting & collecting terrestrial animals
- 5.4 Fishing & harvesting aquatic resources

6. Human intrusions & disturbance

- 6.1 Recreational activities

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

- 9.2 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
- 9.5 Air-borne pollutants
  - 9.5.1 Acid rain
- 9.6 Excess energy
  - 9.6.1 Light pollution

10. Geological events

- 10.2 Earthquakes/tsunamis

11. Climate change & severe weather

- 11.1 Habitat shifting & alteration
- 11.2 Droughts
- 11.3 Temperature extremes
- 11.4 Storms & flooding
- 11.5 Other impacts (sea-level rise)

12. Other options

- 12.1 Other threat (deforestation has been proposed as a managerial action on some overgrown mangroves)

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. 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 values for 1970 should be considered only indicative (see appendix 3 for further details of the methods and limitations).

In contrast, to estimate the Warm Temperate Northwest Pacific 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 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 mangroves in the Warm Temperate Northwest Pacific province increased from 3.54 ha in 1970 to 5.68 ha in 2020, an area gain of approximately 61% over the last 50 years (1970-2020). Given that the change in geographic distribution is positive, the ecosystem is assessed as **Least Concern** under subcriterion A1.

Mangroves of the Warm Temperate Northwest Pacific	Area 2020* (Km^2)	Area 1970* (Km^2)	Net area Change (Km^2)	% Net Area Change	Rate of change (%/year)
	5.68	3.54	2.14	61	1.21%

** 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 Warm Temperate Northwest Pacific province mangroves show a net area change of -24.2% (1996-2020) based on the Global Mangrove Watch time series (Bunting *et al.,* 2022). This value reflects the offset between areas gained (+ 1.1%/year) and lost (- 2.1%/year). However, the national data show a different trend from the GMW with increases in the mangrove area in the last decades. Therefore, the ecosystem is assessed as Least Concern (LC) under criterion A2.

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

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

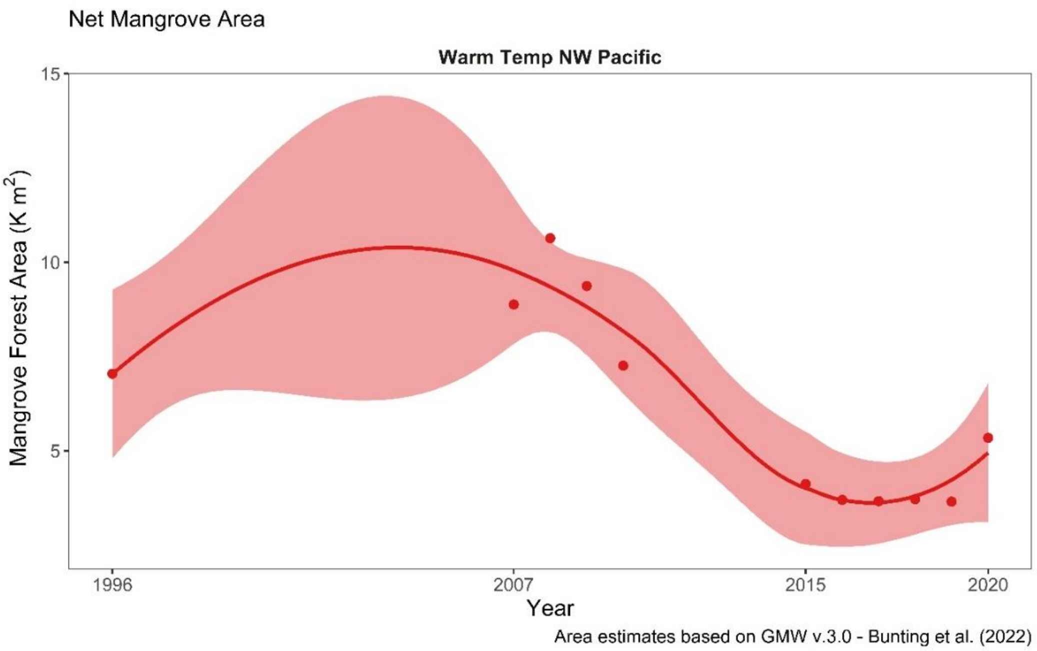

Figure 2. Projected extent of the Warm Temperate Northwest Pacific mangrove ecosystem to 2070. Circles represent the province mangrove area between 1996 and 2020 based on the GMW v3.0 dataset and equations in Bunting *et al*., (2022). The solid line and shaded area are the linear regression and 95% confidence intervals. Squares show the Warm Temperate Northwest Pacific province predicted mangrove area for 2046 and 2070. It is important to note that an exponential model (proportional rate of decline) did not give a better fit to the data (R^2 = 0.5).

Criterion B: Restricted Geographic Distribution

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

Province	Extent of Occurrence EOO (Km^2)	Area of Occupancy (AOO > 1%)	Criterion B
The Warm Temperate Northwest Pacific	61288.4	30	**LC**

For 2020, AOO and EOO were measured as 36 grid cells 10 x 10 km and 61288.4 km^2, respectively (figure 3). Excluding from the AOO those grid cells that contain patches of mangrove forest that account for less than 1% of the grid cell area, (< 1 Km^2), the AOO is measured as **30 10 x 10 km grid cells** (Figure 3, red grids).

The status of the ecosystem does not allow to comply with any of the sub-criteria (a-c), considering there is no continuous decline or plausible threat of causing continuous decline in next 20 years. As result the ecosystem is considered LC for B1 and B2. No plausible threat allowing to identify small number of Threat Defined Locations resulting in LC for B3. As result, the Warm Temp NW Pacific mangrove ecosystem is assessed as Least Concern (LC) under criterion B.

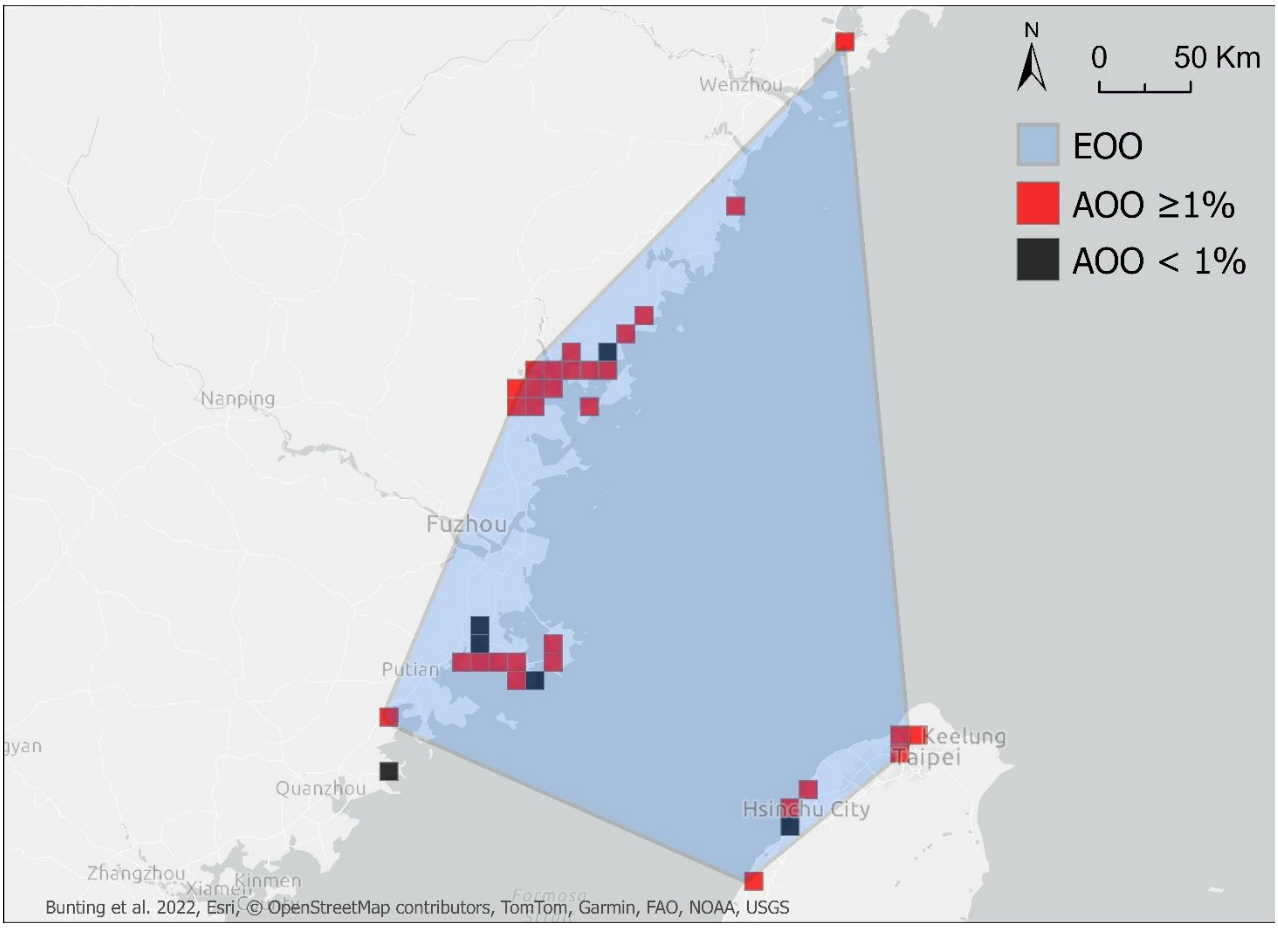

Figure 3. The Warm Temperate Northwest Pacific mangrove Extent Of Occurrence (EOO) and Area Of Occupancy (AOO) in 2020. Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022). The red 10 x 10 km grids (n=30) cover 99% of the ecosystem, accumulated area and the black grids 0 - <1% (n= 6).

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 Warm Temperate Northwest Pacific mangrove ecosystem is classified as **Data Deficient (DD)** for subcriterion C1.

Subcriterion C2 measures environmental degradation in the future, or over any 50-year period, including from the present. In this context, the impact of future sea-level rise (SLR) on mangrove ecosystems was assessed by adopting the methodology presented by Schuerch *et al.* (2018). The published model was designed to calculate both absolute and relative change in the extent of wetland ecosystems under various regional SLR scenarios (i.e medium: RCP 4.5 and high: RCP 8.5), with consideration for sediment accretion. Therefore, Schuerch *et al*. (2018) model was applied to the Warm Temperate Northwest Pacific mangrove ecosystem boundary, using the spatial extent in 2010 (Giri *et al*. (2010) and assuming mangrove landward migration was not possible.

According to the results, under an extreme sea-level rise scenario of 1.1 metres rise by 2100, the projected submerged area is ~ -0.4% by 2060, which remains below the 30% risk threshold. Therefore, considering that no mangrove recruitment can occur in a submerged system (100% relative severity), but that -0.4% of the ecosystem extent will be affected by SLR, the Warm Temperate Northwest Pacific 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 Warm Temperate Northwest Pacific 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 Warm Temperate Northwest Pacific 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), 14.5% of the Warm Temperate Northwest Pacific mangrove area is classified as degraded, resulting in an average annual rate of degradation of 0.9%. Assuming this trend remains constant, +43% of the Warm Temperate Northwest Pacific mangrove area will be classified as degraded over a 50-year period. However, it is important to note that changes observed in vegetation indices may also reflect data artifacts (Akbar et al., 2020) and since the extent of degradation is below 50% (assuming relative severity of more than 50% but less than 80%) the ecosystem won't meet the category thresholds for criterion D, the Warm Temperate Northwest Pacific 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 Warm Temperate Northwest Pacific 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)**.

4. 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	LC
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 Warm Temperate Northwest Pacific mangrove ecosystem is assessed as **Least Concern (LC).**

5. References

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6. Appendices

1. List of Key Mangrove Species

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

Class	Order	Family	Scientific name	RLTS category
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia marina*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Kandelia obovata*	LC
		Primulaceae	*Aegiceras corniculatum*	LC
			Excoecaria agallocha	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
			Phragmites communis		
			Cricotopus sylvestris		
			Tanytarsas formosanus		
			Microchironomus tener		
			Harnischia curtilamellata		
			Polypedilum nubifer		
			Myoporum bontioides		
Phascolosomatidea	Phascolosomatidea		*Phascolosoma arcuatum*		
Bivalvia	Bivalvia		*Glauconome chinensis*		
Gastropoda			*Acteocina koyasensis*		
			Peronia verruculata		
			Batillaria zonalis		
			Pirenella alata		
			Pirenella cingulata		
			Iravadia quadrasi		
			Iravadia reflecta		
			Hyala bella		
			Reishia clavigera		
			Thiara riqueti		
			Thiara tuberculata		
Decapoda			*Mictyris brevidactylus*		
			Tmethypocoelis ceratophora		
			Ilyograpsus paludicola		
			Helice formosensis		
			Pseudohelice subquadrata		
			Metaplax longipes		
			Liza macrolepis		

Class	Order	Family	Scientific name	RLTS category	Common name
			Oreochromis hybrids		
			Anas crecca		
			Ardea cinerea		
			Bubulcus ibis		
			Phascolosoma esculenta		
			Alpheus distinguendus		
			Assiminea brevicula		
			Calidris alpina		
			Egretta garzetta		
			Calidris ruficollis		
			Charadrius alexandrinus		

3. National Estimates for subcriterion A1

To estimate the Warm Temperate Northwest Pacific 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 Warm Temperate Northwest Pacific 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. Lin et al. (2019)

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**
North-western coast of Taiwan	680.7	198.8	178.0	53.7
The Warm Temperate Northwest Pacific		**0**		**0**

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

Country	Year	Mangrove Area (Ha)	Reference
North-western coast of Taiwan	1976	53.7	Lin HJ, Ho CW, Chen TY (2019). Surveys on Mangrove Ecosystems. Ocean Conservation Administration, Ocean Affairs Council.
North-western coast of Taiwan	1986	56.7	Lin HJ, Ho CW, Chen TY (2019). Surveys on Mangrove Ecosystems. Ocean Conservation Administration, Ocean Affairs Council.
North-western	1996	98.1	Lin HJ, Ho CW & Chen TY (2019). Surveys on Mangrove Ecosystems. Ocean Conservation Administration, Ocean Affairs Council.

coast of Taiwan			
North-western coast of Taiwan	2006	150.9	Lin HJ, Ho CW & Chen TY (2019). Surveys on Mangrove Ecosystems. Ocean Conservation Administration, Ocean Affairs Council.
North-western coast of Taiwan	2011	221.0	Lin HJ, Ho CW & Chen TY (2019) Surveys on Mangrove Ecosystems. Ocean Conservation Administration, Ocean Affairs Council.
North-western coast of Taiwan	2019	181.1	Lin HJ, Ho CW & Chen TY (2019) Surveys on Mangrove Ecosystems. Ocean Conservation Administration, Ocean Affairs Council.
North-western coast of Taiwan	2023	198.8	Lin HJ, Ho CW & Chen TY (2019). Surveys on Mangrove Ecosystems. Ocean Conservation Administration, Ocean Affairs Council.
Wenzhou, Zhejiang	1957	10	Qiu, J., Huang, L., Chen, S., Chi, W., Ding, W., Zhou, C., Zheng, C. & Wang, W. (2010). Critical tidal level for *Kandelia candel* forestation in strong tidal range area [J]. Chinese Journal of Applied Ecology, 21(5):1252-1257. (in Chinese with English abstract)
Wenzhou, Zhejiang	1966	300	Zhejiang Mariculture Research Institute
Wenzhou, Zhejiang	1990	17	Wu, P., Zhang, J., Ma, *et a*l., 2013.Remote sensing monitoring and analysis of the changes of mangrove resources in China in the past 20 years. Advances in Marine Science 31:406-414. (in Chinese with English abstract)
Wenzhou, Zhejiang	2002	21	Zheng, J., Chen, Q., Wang, J., *et al*., 2011. The present status of mangrove wetlands in Zhejiang and its spatial function investigation. Journal of Zhejiang Agriculture Science, 2:291-295. (in Chinese)
Wenzhou, Zhejiang	2011	141	State Forestry Administration, Reports of mangrove resources survey in China, 2002
Taizhou, Zhejiang	2011	6	State Forestry Administration, Reports of mangrove resources survey in China, 2002
Wenzhou, Zhejiang	2015	169	Chen, Q, Zheng, J., Wang, J., 2015. Planted Mangroves in Zhejiang Province [M], China Forestry China Forestry Publishing House, Beijing, 140pp. (in Chinese)
Taizhou, Zhejiang	2015	93	Chen, Q, Zheng, J., Wang, J., 2015. Planted Mangroves in Zhejiang Province [M], China Forestry China Forestry Publishing House, Beijing, 140pp. (in Chinese)
Wenzhou, Zhejiang	2018	107	Wu W., Zhao, Z., Yang, S., *et al*., 2022. The mangrove forest distribution and analysis of afforestation effect in Zhejiang Province. Journal of Tropical Oceanography, 41:67-74. (in Chinese with English abstract)
Taizhou, Zhejiang	2018	16	Wu W., Zhao, Z., Yang, S., *et al*., 2022. The mangrove forest distribution and analysis of afforestation effect in Zhejiang Province. Journal of Tropical Oceanography, 41:67-74. (in Chinese with English abstract)
Wenzhou, Zhejiang	2020	257	Wu W., Zhao, Z., Yang, S., *et al*., 2022. The mangrove forest distribution and analysis of afforestation effect in Zhejiang Province. Journal of Tropical Oceanography, 41:67-74. (in Chinese with English abstract)
Taizhou, Zhejiang	2020	130	Wu W., Zhao, Z., Yang, S., *et al*., 2022. The mangrove forest distribution and analysis of afforestation effect in Zhejiang Province. Journal of Tropical Oceanography, 41:67-74. (in Chinese with English abstract)
Wenzhou, Zhejiang	2023	363	Department of Forestry of Zhejiang Province (2023). A brief report on the progress of forestry work, volume 26, special collection 32. (http://lyj.zj.gov.cn/art/2023/5/31/art_1229618174_59052705.html)
Taizhou, Zhejiang	2023	121	Department of Forestry of Zhejiang Province (2023). A brief report on the progress of forestry work, volume 26, special collection 32. (http://lyj.zj.gov.cn/art/2023/5/31/art_1229618174_59052705.html)
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.