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Mangroves of the South Kuroshio

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Abstract

Mangroves of the South Kuroshio is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology). It includes the marine ecoregions of the Central Kuroshio Current and South Kuroshio. In 2020, the mapped extent of the South Kuroshio mangrove province was 8.0 km^2, representing less than 0.01% of the global mangrove area; the biota is characterized by 19 true mangrove species.

Mangroves in this province are now well conserved, and their distribution is tending to expand through natural processes. Because this province is close to the northern limit of mangrove distribution, mangrove flora and fauna are adapted to low temperatures and distinct seasonality. Many of the effects of climate warming on the organisms living among mangroves remain unclear and need to be monitored.

In 2020, the South Kuroshio mangroves cover 43% more area than our estimate for 1970. Since 1996, there has been a net increase in mangrove area of 0.39%. Although this trend might continue linearly over the next 50 years, in reality, the mangrove area should plateau when the maximum potential growth area of mangroves is reached. In contrast, spatially isolated and small-scale mangrove ecosystems are vulnerable in the event of a severe disruption impacting a wide area. Under a high sea-level rise scenario (IPCC RCP8.5) ≈8.2% of the South Kuroshio mangroves would be submerged by 2060. Moreover, 0.43% of the province's mangrove ecosystem is undergoing degradation, with the potential to increase to 1.26% within a 50-year period, based on a vegetation index decay analysis.

Overall, the South Kuroshio 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:
South Kuroshio 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**	

LC: Least Concern, DD Data Deficient, NE: Not Evaluated

Mangroves of the South Kuroshio

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_28 Mangroves of the South Kuroshio

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

1 Forest

1.7 Forest – Subtropical/tropical mangrove vegetation above high tide level*_below water level_ [1]

12 Marine Intertidal

12.7 Mangrove Submerged Roots

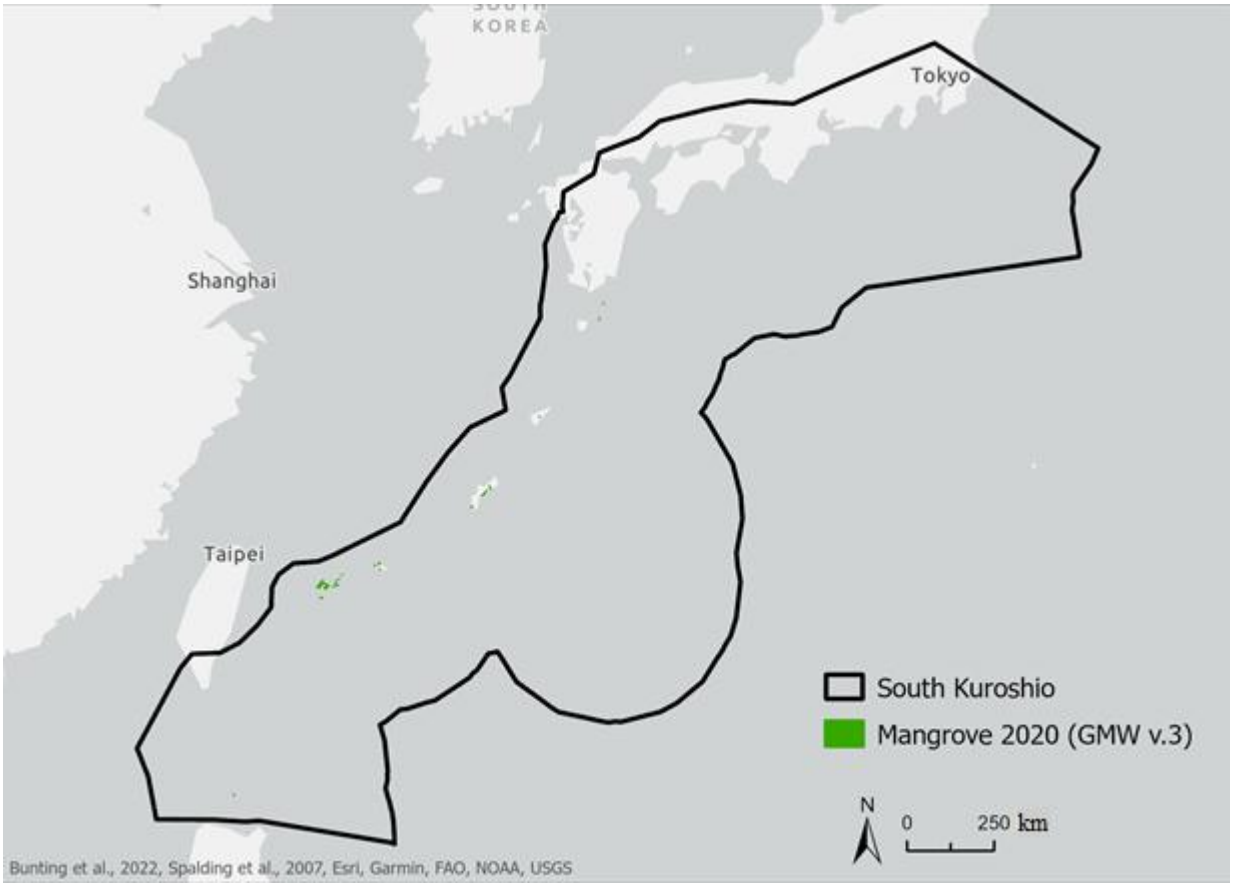

Figure 1. The mangroves of South Kuroshio province.

[1] Note on the original classification scheme. This habitat should include mangrove vegetation below water level. Mangroves have spread into warm temperate regions to a limited extent and may occasionally occur in supratidal areas. However, the vast majority of the world's mangroves are found in tropical/subtropical intertidal areas.

2. Ecosystem Description

Spatial distribution

The mangroves of South Kuroshio province include intertidal forests and shrublands of the marine ecoregions of the Central Kuroshio Current and South Kuroshio that extend across the southern part of Japan, southern Taiwan, and Calayan Island in the Philippines, however, mangroves are restricted almost entirely to southern Japan (Figure 1). Mangroves are distributed in Kagoshima and Okinawa Prefectures in southern Japan, with more than 90% of them occurring in Okinawa Prefecture. In 2020, the mangrove extent in Japan was 7.97 km^2, representing less than 0.01% of global mangrove area. However, these mangroves are significant because they are at the northern limit of mangrove distribution in the Indo-Pacific region. The largest concentration of mangrove forest (1.22 km^2) is in the Nakama River basin on Iriomote Island in Okinawa Prefecture.

According to the Global Mangrove Watch dataset (Bunting *et al*., 2022), based on satellite imagery, the mangrove area of South Kuroshio was 10.4 km^2 in 2020. However, because the national data are based on analyses of aerial photographs and satellite imagery, and both were supported by ground truthing, they were selected in the present analysis of mangrove area change (Figure 2a and b).

Mangroves of the Urauchi River on Iriomote Island (Okinawa Prefecture, Japan)
(Photo credit: Shigeyuki Baba)

The mangroves in this province are expanding naturally because most are well-conserved. All areas with mangroves on Iriomote Island have been designated as part of a national park, and in 2021 the entire island was designated as a Natural World Heritage Site (UNESCO World Heritage Centre, 2021). Since 1996, the mangrove extent of these marine ecoregions has increased by a net 0.39% (ISME, 2004; Inoue *et al*., 2022a).

Biotic components of the ecosystem (characteristic native biota)

The mangroves of the South Kuroshio province are biologically diverse with 19 recorded true mangrove plant species (IUCN, 2022; Appendix 1). There are at least 174 species within the Actinopterygii, Aves, Bivalvia, Chondrichthyes, Gastropoda, Insecta, Magnoliopsida, Mammalia and Reptilia, associated with mangrove habitats in the IUCN Red List of Threatened Species (IUCN, 2022; Appendix 2). Among these species, the Green sawfish (*Pristis zijsron*) is critically endangered (CR); four species are endangered (EN): *Himantura uarnak, Negaprion acutidens, Maculabatis macrura, Neophocaena asiaeorientalis*); nine are Vulnerable (VU): *Albula glossodonta, Carcharhinus amblyrhynchoides, Carcharhinus amboinensis Carcharhinus melanopterus, Dugong dugon, Egretta eulophotes, Himantura leoparda, Pastinachus ater, Pteropus dasymallus*; and four are Near Threatened (NT): *Anhinga melanogaster, Brownlowia tersa, Numenius Arquata, Terpsiphone atrocaudata* (IUCN, 2022).

The mangroves in Japan are comprised of the following true mangrove species: three species of Rhizophoraceae (*Rhizophora stylosa*, *Bruguiera gymnorhiza*, and *Kandelia obovata*), one species of Acanthaceae (*Avicennia marina*), one species of Lythraceae (*Sonneratia alba*), and one species of Combretaceae (*Lumnitzera racemosa*). This province is phytogeographically important as the northern limit of the native distribution of *Nypa fruticans, R. stylosa, B. gymnorhiza, K. obovata, S. alba, L. racemosa, Excoecaria agallocha,* and *Heritiera littoralis* (IUCN, 2022).

Abiotic components of the ecosystem

Regional distributions of mangroves are influenced by interactions among landscape position, rainfall, hydrology, sea level, ground level, sediment dynamics, and storm-driven processes. 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. The inorganic components of mangrove sediment consist of terrestrial-derived sand and coral-derived sand (main component: calcium carbonate) depending on processes such as river inflow and coral sand deposition. Many mangrove soils in this province are low in nutrients, especially nitrogen and phosphorus, particularly where there is less inflow from residential land, farmlands, or pastures.

Mangroves in this province are near the northern limit of their distribution; thus, low winter temperatures and extreme cold snaps sometimes affect mangrove growth. In the northernmost part of this province, in Kagoshima Prefecture, there are populations of dwarf *K. obovata*, which may be partly due to the combination of low temperatures and high salinities.

Key processes and interactions

Mangroves act as structural engineers, with traits such as aerial roots, salt tolerance, vivipary, and propagule buoyancy that promote survival and recruitment in saline, mobile, poorly aerated, and tidally inundated substrata. They exhibit high efficiency in nitrogen use and nutrient resorption. Species of Acanthaceae and Rhizophoraceae are known to achieve high levels of nitrogen fixation via diazotrophs

around their roots (Inoue *et al*., 2019; 2020; 2024). Around the roots of smaller and therefore likely younger trees, the diazotrophic community most closely resembles that found in unvegetated mudflats, but as the trees grow and develop higher root biomass, it evolves to recruit plant-growth-promoting bacteria (Inoue *et al*., 2020). The relationship between Rhizophoraceae mangroves and arbuscular mycorrhizal fungi are formed depending on salinity (Akaji *et al*., 2022; 2024).

Even on low-nutrient tidal flats, mangroves produce large amounts of detritus (e.g., leaves, twigs, and bark), which are buried in waterlogged sediments, consumed by crabs and gastropods, and then decomposed further by meiofauna, fungi and bacteria, thereby mobilising carbon and nutrients to other trophic levels in the mangrove and coastal food web.

Mangrove ecosystems also serve as major blue carbon sinks, incorporating organic matter into sediments and living biomass. Mangrove soils tend to be saline and anaerobic due to repeated tidal flooding, which slows the rate of decomposition of organic matter, and this can contribute to the high accumulation of carbon in mangrove soils. Field measurements of soil carbon storage to a depth of 100 cm in this province showed 195–497 Mg C ha $^{-1}$ in mangroves of Iriomote Island (Fujimoto *et al*., 2000; Fujimoto *et al*., 2002) and 123 Mg C ha $^{-1}$ in mangroves of Amami-oshima (Ishihara *et al*., 2004).

2. Ecosystem Threats and Vulnerabilities

Main threatening process and pathways to degradation

Drifted trash from neighbouring countries in a small mangrove stream on Iriomote Island (Photo credit: Shigeyuki Baba)

Very few mangroves in the South Kuroshio province have been harvested for charcoal-making or building materials, or converted to aquaculture ponds. Mangroves in this province were partly cut in the 1950s (after the Pacific War) due to development of coastal areas, construction of coastal roads and concrete revetment works, and river rehabilitation; however, the remaining mangroves are now well conserved, and their

distribution is tending to expand through natural processes, such as habitat expansions by sedimentation and reproductive dispersal.

The mangroves are regarded as a tourist attraction, with the annual number of people visiting mangrove areas for tourism being more than a hundred times the number of residents. Care has been taken to minimise the impact of tourism on the ecosystem, such as limiting the speed of tourist boats and providing guidance to tourists not to harm plants and animals. Another impact is the garbage washed ashore by the Kuroshio Current. In some areas, regular cleaning has been carried out by local groups, but not everything can be cleaned.

Although there is little direct human impact, many of the coastal areas in this province are close to mountains and thus have only small areas of tidal flats, which means that mangrove habitats will be affected by sea-level rise (see photograph). Because this province is close to the northern limit of mangrove distribution, mangrove flora and fauna have adapted to low temperatures and distinct seasonality. Many of the effects of climate warming on these cold-adapted mangrove organisms, such as changes in seasonality and increased temperature, remain unclear and need to be monitored. Moreover, it is becoming clear that mangrove plant responses to temperature, and their survival temperature ranges, differ among species (Inoue *et al*., 2022b; Inoue *et al*., 2023).

Many of the coastal areas in South Kuroshio province are close to mountains and thus have small areas of tidal flats (Photo credit: Tomomi Inoue)

Definition of the collapsed state of the ecosystem

The alteration of the topography of the land itself, and the disappearance of the flora as primary producers, can lead to the destruction of ecosystems. Located in the interface between land and sea, mangrove ecosystems are formed under the influence of a balance of physical, chemical, and biological processes both

terrestrial and marine; this balance may be affected by changes in these processes. Large-scale physical destruction can be identified visually as a change in the landscape of the ecosystem itself. In addition, the restricted distribution of mangroves within warm regions of the world suggests that mangrove ecosystems are significantly affected by temperature.

Widespread dieback after a big typhoon (Iriomote Island, Japan)
(Photo credit: Tomomi Inoue)

On the basis of the global pattern of mangrove distribution, it has been suggested that mangroves occur in habitats where the mean winter temperature of the water surface is above 20 °C (Duke *et al*., 1998). Extreme freezing events may determine the poleward limits of mangrove distribution (Osland *et al*., 2014; 2015; 2017). The effects of extreme cold snaps can be seen in leaf damage and defoliation of trees. Defoliation due to extreme cold snaps are sometimes observed in Kagoshima Prefecture (see photograph). Dieback due to a big typhoon is also observed in this province (see photograph). Changes in the frequency and intensity of these extreme events, as a results of climate warming, could affect the growth and distribution of mangroves. In contrast, the effects of gradual climate change are difficult to detect visually, but the physiology and growth of flora and fauna are affected.

Threat classification

IUCN Threat Classification (version 3.3, IUCN-CMP, 2022) relevant to mangroves of the South Kuroshio province:

1. Residential & commercial development
- 1.3 Tourism & recreation areas

6. Human intrusions & disturbance
- 6.1 Recreational activities

9. Pollution
- 9.1 Domestic & urban waste water
  - 9.1.2 Run-off
- 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
  - 9.5.3 Ozone

10. Geological events
- 10.1 Volcanoes
- 10.2 Earthquakes/tsunamis
- 10.3 Avalanches/landslides

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)

3. 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, there are mangrove area estimates for Okinawa Prefecture in 1977 and 1997 based on an aerial photo analysis with ground truth data. The mangrove area in Okinawa is equivalent to ~90% of the entire mangrove area of this province. In addition to those data, we have estimated the mangrove area in

2020 with the satellite image analysis. The estimates of mangrove extent can be used to extrapolate the trend between 1970 and 2020. The estimated values for 1970 should be considered only indicative (see Appendix 3 for further details of the methods and limitations).

Results from the analysis of subcriterion A1 (Appendix 3) show that the area of mangroves in the South Kuroshio mangrove province increased approximately 43% over the last 50 years (1970–2020) because the mangroves in this province have been well conserved. Given that the geographic distribution is expanding naturally, the ecosystem is assessed as **Least Concern (LC)** under subcriterion A1.

Mangroves of the South Kuroshio**	Area 2020* (km^2)	Area 1970* (km^2)	Net Area Change (km^2)	% Net Area Change	Rate of Change (%/year)
	7.3	5.1	2.2	43.0	0.87

** Details on the methods and references used to estimate the mangrove area in 1970 and 2020 are listed in appendix 3.*
***The area in this table represents mangrove extent in Okinawa Prefecture, which correspond to ~90% of the entire mangrove area of the South Kuroshio*

Subcriterion A2 assesses changes in ecosystem extent over 50-year periods, spanning from the present to the future. According to data from the Global Mangrove Watch time series (Bunting et al., 2022), the mangroves in South Kuroshio experienced a net area change of -0.6% between 1996 and 2020 (Figure 2b), with the largest decline occurring between 2007 and 2015. However, due to its non-linear nature, it is not appropriate to predict future mangrove extent or to assume a linear trend over the next 50 years with this dataset and therefore won't be considered for criteria A2.

Conversely, according to the national data for Okinawa Prefecture (Appendix 3), the mangrove area in the South Kuroshio province has increased at a net rate of 0.86%/year from 1977 to 2020, a net increase of 37% (Figure 2a). Although a linear projection using these data shows a large increase of 31.7% from 2020 to 2070, in reality the mangrove area should plateau when the maximum potential growth area of mangroves is reached. Thus, the South Kuroshio mangrove ecosystem is assessed as **Least Concern (LC)** under subcriterion 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 South Kuroshio mangrove ecosystem is classified as **Data Deficient (DD)** for this subcriterion.

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

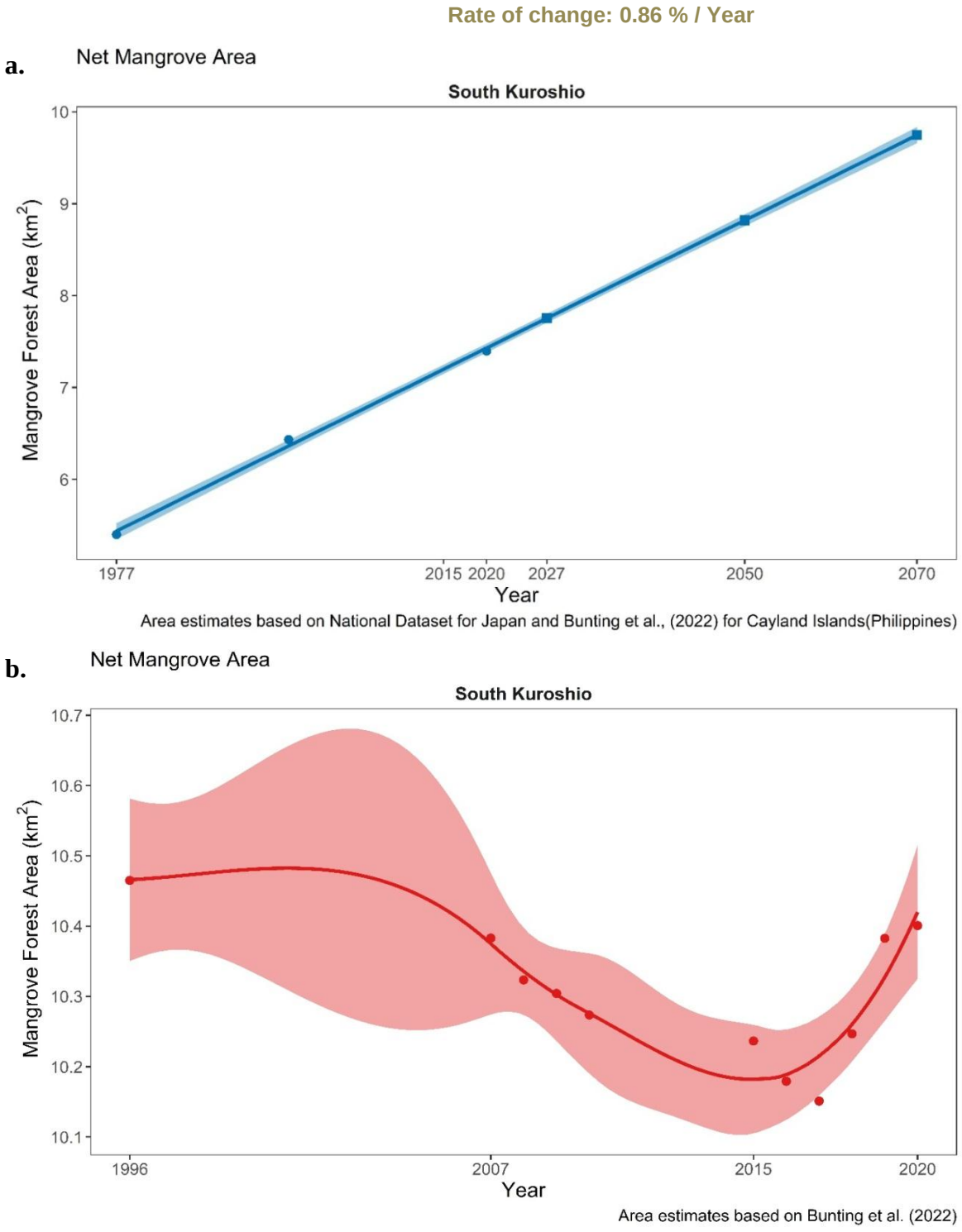

Figure 2. South Kuroshio mangrove ecosystem area a). between 1977 and 2020 (circles) with projections to 2027 and 2070 (squares). The solid line and shaded area show the linear trend and 95% confidence intervals. Estimated areas are based on national datasets for the Japanese portion of the ecosystems (Appendix 3) and Bunting et al., 2022 for the Caylan Islands (Philippines). Although a linear increase has been projected for 2070, in reality, the mangrove area should plateau when the maximum potential growth area of mangroves is reached. The solid line and shaded area are the linear regression and 95% confidence intervals. b). between 1996 and 2020 (circles) based on the GMW v3.0 dataset and equations in Bunting et al., (2022). The solid line shows a loess regression and shaded area represents 95% confidence interval.

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 mangrove extent in South Kuroshio province in 2020 by the Global Mangrove Watch Version 3 (GMW v3.0) dataset (Bunting *et al*., 2022).

Province	Extent of Occurrence EOO (km^2)	Area of Occupancy (AOO ≥ 1 %)	Criterion B
The South Kuroshio	170767.0	24	**LC**

For 2020, AOO and EOO were measured as 24 grid cells 10 x 10 km and 170767.0 km^2, respectively (Figure 3). After excluding from total of 36 those grid cells that collectively contain small patches covering less than 1% of the total mapped area of the ecosystem, the AOO is estimated as 24 grid cells (10 x 10 km) (Figure 3, red grids).

The status of well-managed ecosystems including marine areas, 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 the next 20 years. As a result, the ecosystem is considered LC for B1 and B2. There are no plausible threats allowing identification of Threat Defined Locations, resulting in LC for B3. Thus, the South Kuroshio mangrove ecosystem is assessed as **Least Concern (LC)** under criterion B.

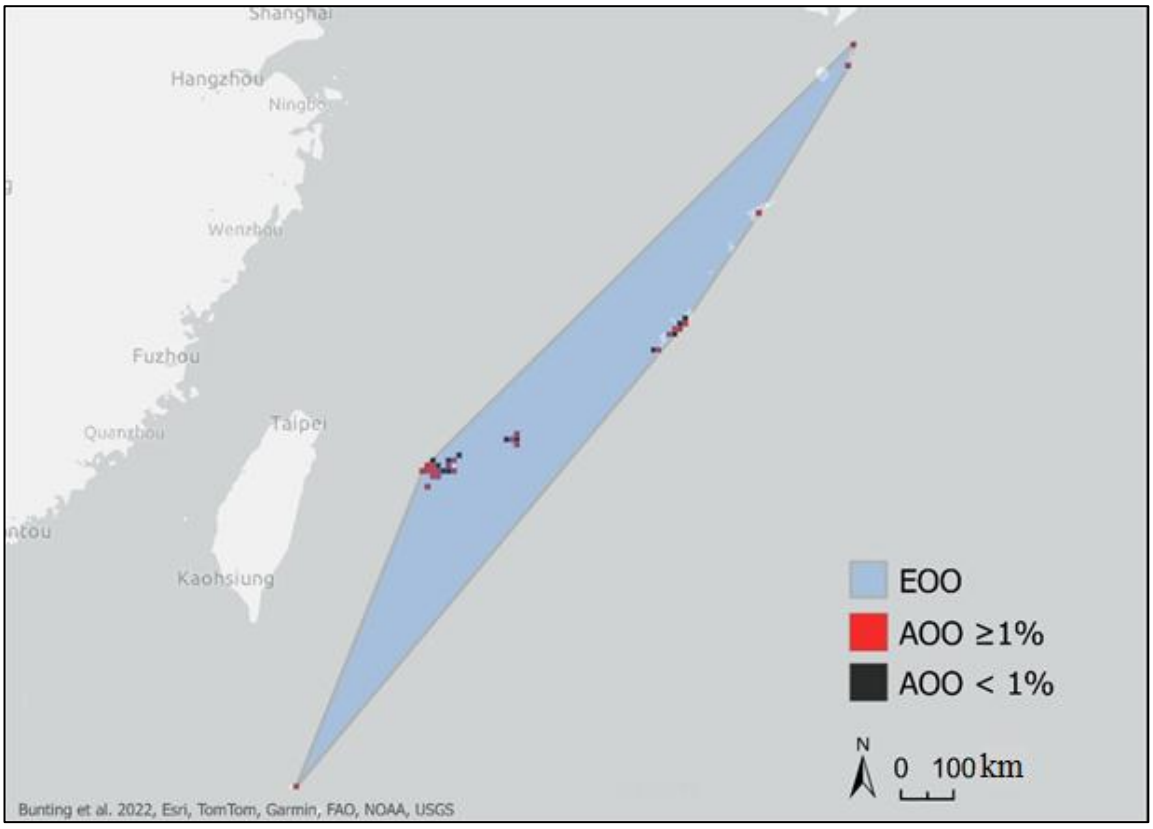

Figure 3. The South Kuroshio mangrove Extent Of Occurrence (EOO) and Area Of Occupancy (AOO) in 2020. Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022). The red 10 x 10 km grids (n = 24) cover 99% of the ecosystem, accumulated area and the black grids 0 - 1% (n = 12).

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 Kuroshio 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 South Kuroshio mangrove ecosystem boundary, with spatial extent based on Giri *et al*., (2011) and assuming mangrove landward migration was not possible.

According to the results, under an extreme sea-level rise scenario of a 1.1-meter rise by 2100, the projected submerged area is ~ -8.2% 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 -8.2% of the ecosystem extent will be affected by SLR, the South Kuroshio 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 South Kuroshio 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 South Kuroshio 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,

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), 0.43% of the South Kuroshio mangrove area is classified as degraded, resulting in an average annual rate of degradation of 0.03%. Assuming this trend remains constant, 1.26% of the South Kuroshio mangrove area will be classified as degraded over a 50-year period. Since less than 30% of the ecosystem will meet the category thresholds for criterion D, the South Kuroshio mangrove province is assessed as **Least Concern** (**LC)** under subcriterion D2.

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 Kuroshio 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 50year 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 50year period	**C3** Historical (1750)
	DD	**LC**	**DD**
D. Disruption of Biotic Processes	**D1** Past 50 years (1970)	**D2** Future or Any 50year 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 South Kuroshio mangrove ecosystem is assessed as **Least Concern (LC).**

6. References

Akaji, Y., Inoue, T., Taniguchi, T., & Baba S. (2022). Arbuscular mycorrhizal fungal communities of a mangrove forest along a salinity gradient on Iriomote Island. *Plant and Soil*, *472*, 145–159. https://doi.org/10.1007/s11104-021-05193-4

Akaji, Y., Inoue, T., Kohzu, A., Taniguchi, T., & Baba, S. (2024). *Bruguiera gymnorhiza* forms mycorrhizal associations but *Rhizophora stylosa* does not: A pot experiment using mangrove soil and Rhizophoraceae seedlings. *Aquatic Botany*, *192*, 103748. https://doi.org/10.1016/j.aquabot.2023.103748

Akbar, M. R., Arisanto, P. A. A., Sukirno, B. A., Merdeka, P. H., Priadhi, M. M., & Zallesa, S. (2020). Mangrove vegetation health index analysis by implementing NDVI (normalized difference vegetation index) classification method on sentinel-2 image data case study: Segara Anakan, Kabupaten Cilacap. *IOP Conference Series: Earth and Environmental Science*, *584*(1), 012069. https://doi.org/10.1088/1755-1315/584/1/012069.

Aljahdali, M. O., Munawar, S., & Khan, W. R. (2021). Monitoring Mangrove Forest Degradation and Regeneration: Landsat Time Series Analysis of Moisture and Vegetation Indices at Rabigh Lagoon, Red Sea. *Forests*, *12*(1), 52. https://doi.org/10.3390/f12010052

Bunting, P., Rosenqvist, A., Hilarides, L., Lucas, R. M., Thomas, N., Tadono, T., Worthington, T. A., Spalding, M.D., Murray, N. J., & Rebelo, L.-M. (2022). Global Mangrove Extent Change 1996–2020: Global Mangrove Watch Version 3.0. *Remote Sensing*, *14*(15), 3657. https://doi.org/10.3390/rs14153657

Duke, N. C., Ball, M. C., & Ellison, J. C. (1998). Factors influencing biodiversity and distributional gradients in mangroves. *Global Ecology and Biogeography Letters*, *7*(1), 27–47. https://doi.org/10.1111/j.1466-8238.1998.00269.x

Fujimoto, K., Ishihara, S., Yukino, I., et al. (2000). Evaluation of carbon sequestration in mangrove ecosystem with its habitat dynamics in Iriomote Island, Southwestern Japan. In Proceedings of the general meeting of the Association of Japanese Geographers, 58, p 60–61. [In Japanese]

Fujimoto, K., Miyagi, T., Kawaguchi, S., et al. (2002). Carbon sequestration in mangrove ecosystems with its habitat dynamics in Iriomote Island, Southwestern Japan. In: Research Institute for Subtropical Regions (ed) Research report on mangroves. Naha, p 309–319. [In Japanese]

Giri, C., Ochieng, E., Tieszen, L. L., Zhu, Z., Singh, A., Loveland, T., Masek, J., & Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography*, *20*(1), 154–159. https://doi.org/10.1111/j.1466-8238.2010.00584.x

Inoue, T., Kohzu, A., & Shimono, A. (2019). Tracking the route of atmospheric nitrogen to diazotrophs colonizing buried mangrove roots. *Tree Physiology*, *39*(11), 1896–1906. https://doi.org/10.1093/treephys/tpz088

Inoue, T., Shimono, A., Akaji, Y., Baba, S., Takenaka, A., & Chan, H. T. (2020). Mangrove-diazotroph relationships at the root, tree and forest scales: diazotrophic communities creates high soil nitrogenase activities in *Rhizophora stylosa* rhizospheres. *Annals of Botany*, *125*(1), 131–144. https://doi.org/10.1093/aob/mcz164

Inoue, T., Kohzu, A., Akaji, Y., Miura, S., & Baba, S. (2022a). Mangroves of Japan. In T. Pullaiah (ed) A book on Mangroves: Biodiversity, livelihoods and conservation, Springer.

Inoue, T., Akaji, Y., & Noguchi, K. (2022b). Distinct responses of growth and respiration to growth temperatures in two mangrove species. *Annals of Botany*, *129*(1), 15–28. https://doi.org/10.1093/aob/mcab117

Inoue, T., Akaji, Y., Baba, S., & Noguchi, K. (2023). Temperature dependence of O_2 respiration in mangrove leaves and roots: implications for seedling dispersal phenology. *New Phytologist*, *237*(1), 100–112. https://doi.org/10.1111/nph.18513

Inoue, T., Kohzu, A., Akaji, Y., Miura, S., & Baba, S. (2024). Diazotrophic nitrogen fixation through aerial roots occurs in *Avicennia marina*: implications for adaptation of mangrove plant growth to low-nitrogen tidal flats. *New Phytologist*, *241*(4), 1464–1475. https://doi.org/10.1111/nph.19442

Ishihara, S., Fujimoto, K., Kawanishi, M., et al. (2004). Relationship between mangrove vegetation and micro-topography and carbon storage of *Kandelia candel* (L.) Druce forests in Amani-ohshima Island, southwestern Japan. *Japanese Journal of Forest Environment*, *46*, 9–14. [In Japanese]

ISME (2004). Mangrove distribution survey in Okinawa prefecture for the purpose of monitoring coastal ecosystems and sea level rise. Okinawa prefecture commissioned survey research in fiscal year 2003. International Society for Mangrove Ecosystems, Okinawa, p 153. [In Japanese]

IUCN (2012). *IUCN Habitats classification scheme* (3.1). [Data set]. https://www.iucnredlist.org/resources/habitat-classification-scheme.

IUCN (2022). *The IUCN Red List of Threatened Species.* (Version 2022-2) [Data set]. https://www.iucnredlist.org

IUCN-CMP (2022). *Unified Classification of Direct Threats* (3.3) [Data set]. https://www.iucnredlist.org/resources/threat-classification-scheme.

Keith, D. A., Ferrer-Paris, J. R., Nicholson, E., & Kingsford, R. T. (Eds.) (2020). *IUCN Global Ecosystem Typology 2.0: Descriptive profiles for biomes and ecosystem functional groups*. IUCN, International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2020.13.en

Lee, C. K. F., Duncan, C., Nicholson, E., Fatoyinbo, T. E., Lagomasino, D., Thomas, N., Worthington, T. A., & Murray, N. J. (2021). Mapping the Extent of Mangrove Ecosystem Degradation by Integrating an Ecological Conceptual Model with Satellite Data. *Remote Sensing*, *13*(11), 2047. https://doi.org/10.3390/rs13112047

Lovelock, C. E., Feller, I. C., Reef, R., Hickey, S., & Ball, M. C. (2017). Mangrove dieback during fluctuating sea levels. *Scientific Reports*, *7*(1), 1680. https://doi.org/10.1038/s41598-017-01927-6

Murray, N. J., Keith, D. A., Tizard, R., Duncan, A., Htut, W. T., Oo, A. H., Ya, K. Z., & Grantham, M. (2020). *Threatened ecosystems of Myanmar: An IUCN Red List of Ecosystems Assessment. Version 1*. Wildlife Conservation Society. https://doi.org/10.19121/2019.Report.37457

Osland, M. J., Day, R. H., Larriviere, J. C., & From, A. S. (2014). Aboveground allometric models for freeze-affected black mangroves (*Avicennia germinans*): Equations for a climate sensitive mangrove-marsh ecotone. *PLoS ONE*, *9*(6), e99604. https://doi.org/10.1371/journal.pone.0099604

Osland, M. J., Day, R. H., From, A. S., McCoy, M. L., McLeod, J. L., & Kelleway, J. J. (2015). Life stage influences the resistance and resilience of black mangrove forests to winter climate extremes. *Ecosphere*, *6*(9), 160. http://dx.doi.org/10.1890/ES15-00042.1

Osland, M. J., Day, R. H., Hall, C. T., Brumfield, M. D., Dugas, J. L., & Jones, W. R. (2017). Mangrove expansion and contraction at a poleward range limit: climate extremes and land-ocean temperature gradients. *Ecology*, *98*(1), 125–137. https://doi.org/10.1002/ecy.1625

Santana, N. (2018). Fire Recurrence and Normalized Difference Vegetation Index (NDVI) Dynamics in Brazilian Savanna. *Fire*, *2*(1), 1. https://doi.org/10.3390/fire2010001

Schuerch, M., Spencer, T., Temmerman, S., Kirwan, M. L., Wolff, C., Lincke, D., McOwen, C. J., Pickering, M. D., Reef, R., Vafeidis, A. T., Hinkel, J., Nicholls, R. J., & Brown, S. (2018). Future response of

global coastal wetlands to sea-level rise. *Nature*, *561*(7722), 231–234. https://doi.org/10.1038/s41586-018-0476-5

Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., Halpern, B. S., Jorge, M. A., Lombana, A., Lourie, S. A., Martin, K. D., McManus, E., Molnar, J., Recchia, C. A., & Robertson, J. (2007). Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. *BioScience*, *57*(7), 573–583. https://doi.org/10.1641/B570707

UNESCO World Heritage Center (2021) Four natural and three cultural sites added to UNESCO's World Heritage List. https://whc.unesco.org/en/news/2318/

Worthington, T.A., & Spalding, M. D. (2018). *Mangrove Restoration Potential: A global map highlighting a critical opportunity*. Apollo - University of Cambridge Repository. https://doi.org/10.17863/CAM.39153

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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
Polypodiopsida	Polypodiales	Pteridaceae	*Acrostichum aureum*	Least Concern
Magnoliopsida	Ericales	Primulaceae	Aegiceras corniculatum*	Least Concern
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia marina*	Least Concern
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia officinalis**	Least Concern
Magnoliopsida	Lamiales	Acanthaceae	*Avicennia rumphiana**	Vulnerable
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera gymnorhiza*	Least Concern
Magnoliopsida	Malpighiales	Rhizophoraceae	*Ceriops tagal*	Least Concern
Magnoliopsida	Malpighiales	Euphorbiaceae	*Excoecaria agallocha*	Least Concern
Magnoliopsida	Malpighiales	Rhizophoraceae	*Kandelia obovata*	Least Concern
Magnoliopsida	Myrtales	Combretaceae	*Lumnitzera littorea**	Least Concern
Magnoliopsida	Myrtales	Combretaceae	*Lumnitzera racemosa*	Least Concern
Liliopsida	Arecales	Arecaceae	*Nypa fruticans*	Least Concern
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora apiculata**	Least Concern
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora mucronata**	Least Concern
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora stylosa*	Least Concern
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia alba*	Least Concern
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia caseolaris**	Least Concern
Magnoliopsida	Sapindales	Meliaceae	*Xylocarpus granatum**	Least Concern
Magnoliopsida	Malvales	Malvaceae	*Heritiera littoralis*	Least Concern

*These species are distributed in the Philippines.

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 presence recorded as “Extant”, “Possibly Extant” or “Possibly Extinct”, Origin recorded as "Native" or "Reintroduced" , with any value of Seasonality except “Passage”, suitability recorded as “Suitable”, and with “Major Importance” recorded as “Yes”. The common names are those shown in the RLTS, except common names in brackets, which are from other sources.

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Albuliformes	Albulidae	*Albula glossodonta*	Vulnerable	Shortjaw bonefish
Actinopterygii	Anguilliformes	Muraenidae	*Gymnothorax monochrous*	Least concern	
Actinopterygii	Anguilliformes	Muraenidae	*Gymnothorax punctatofasciatus*	Least concern	Bars'n spots moray
Actinopterygii	Anguilliformes	Muraenidae	*Uropterygius concolor*	Least concern	Brown moray eel
Actinopterygii	Anguilliformes	Ophichthidae	*Scolecenchelys macroptera*	Least concern	
Actinopterygii	Atheriniformes	Atherinidae	*Atherinomorus lacunosus*	Least concern	Hardyhead silverside

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Aulopiformes	Synodontidae	*Saurida nebulosa*	Least concern	Clouded lizardfish
Actinopterygii	Beloniformes	Zenarchopteridae	*Zenarchopterus dispar*	Least concern	Feathered river-garfish
Actinopterygii	Clupeiformes	Clupeidae	*Anodontostoma selangkat*	Least concern	Indonesian gizzard shad
Actinopterygii	Clupeiformes	Clupeidae	*Nematalosa nasus*	Least concern	Bloch's gizzard shad
Actinopterygii	Clupeiformes	Clupeidae	*Sardinella albella*	Least concern	White sardinella
Actinopterygii	Clupeiformes	Clupeidae	*Sardinella melanura*	Least concern	Blacktip sardinella
Actinopterygii	Clupeiformes	Engraulidae	*Encrasicholina punctifer*	Least concern	Buccaneer anchovy
Actinopterygii	Elopiformes	Elopidae	*Elops hawaiensis*	Data deficient	Giant herring
Actinopterygii	Elopiformes	Elopidae	*Elops machnata*	Least concern	
Actinopterygii	Elopiformes	Megalopidae	*Megalops cyprinoides*	Data deficient	Indo-pacific tarpon
Actinopterygii	Gobiiformes	Eleotridae	*Bostrychus sinensis*	Least concern	Four-eyed sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Butis amboinensis*	Least concern	Ambon gudgeon
Actinopterygii	Gobiiformes	Eleotridae	*Butis butis*	Least concern	Crimson-tipped gudgeon
Actinopterygii	Gobiiformes	Eleotridae	*Butis koilomatodon*	Least concern	Marblecheek sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Eleotris fusca*	Least concern	Brown spinecheek gudgeon
Actinopterygii	Gobiiformes	Eleotridae	*Eleotris melanosoma*	Least concern	Broadhead sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Eleotris oxycephala*	Least concern	
Actinopterygii	Gobiiformes	Eleotridae	*Ophiocara porocephala*	Least concern	Spangled gudgeon
Actinopterygii	Gobiiformes	Gobiidae	*Amblygobius linki*	Least concern	Link's goby
Actinopterygii	Gobiiformes	Gobiidae	*Asterropteryx semipunctata*	Least concern	
Actinopterygii	Gobiiformes	Gobiidae	*Caragobius urolepis*	Least concern	Scaleless worm goby
Actinopterygii	Gobiiformes	Gobiidae	*Cryptocentrus leptocephalus*	Least concern	Pink-speckled shrimpgoby
Actinopterygii	Gobiiformes	Gobiidae	*Feia nympha*	Least concern	Nymph goby
Actinopterygii	Gobiiformes	Gobiidae	*Glossogobius circumspectus*	Least concern	Circumspect goby
Actinopterygii	Gobiiformes	Gobiidae	*Gnatholepis ophthalmotaenia*	Least concern	
Actinopterygii	Gobiiformes	Gobiidae	*Mahidolia mystacina*	Least concern	Flagfin prawn goby
Actinopterygii	Gobiiformes	Gobiidae	*Mangarinus waterousi*	Data deficient	Uchiwahaze
Actinopterygii	Gobiiformes	Gobiidae	*Mugilogobius cavifrons*	Least concern	Bandfin mangrove goby
Actinopterygii	Gobiiformes	Gobiidae	*Oligolepis acutipennis*	Least concern	Paintedfin goby
Actinopterygii	Gobiiformes	Gobiidae	*Oligolepis stomias*	Data	Plain teardrop

Class	Order	Family	Scientific name	RLTS category	Common name
				deficient	goby
Actinopterygii	Gobiiformes	Gobiidae	*Oxyurichthys lonchotus*	Least concern	Speartail mudgoby
Actinopterygii	Gobiiformes	Gobiidae	*Oxyurichthys ophthalmonema*	Least concern	Eyebrow goby
Actinopterygii	Gobiiformes	Gobiidae	*Parachaeturichthys polynema*	Least concern	Lancet-tail goby
Actinopterygii	Gobiiformes	Gobiidae	*Paratrypauchen microcephalus*	Least concern	Comb goby
Actinopterygii	Gobiiformes	Gobiidae	*Psammogobius biocellatus*	Least concern	Sleepy goby
Actinopterygii	Gobiiformes	Gobiidae	*Redigobius balteatus*	Least concern	Girdled goby
Actinopterygii	Gobiiformes	Gobiidae	*Stenogobius ophthalmoporus*	Least concern	
Actinopterygii	Gobiiformes	Gobiidae	*Taenioides cirratus*	Data deficient	Whiskered eel goby
Actinopterygii	Gobiiformes	Gobiidae	*Trypauchen vagina*	Least concern	Burrowing goby
Actinopterygii	Gobiiformes	Gobiidae	*Trypauchenopsis intermedia*	Least concern	Bearded eel goby
Actinopterygii	Mugiliformes	Mugilidae	*Planiliza subviridis*	Least concern	Greenback mullet
Actinopterygii	Ophidiiformes	Carapidae	*Encheliophis homei*	Least concern	Silver pearlfish
Actinopterygii	Perciformes	Ambassidae	*Ambassis vachellii*	Least concern	Vachell's glassfish
Actinopterygii	Perciformes	Apogonidae	*Apogonichthyoides melas*	Least concern	Black cardinalfish
Actinopterygii	Perciformes	Apogonidae	*Fowleria variegata*	Least concern	Variegated cardinalfish
Actinopterygii	Perciformes	Apogonidae	*Ostorhinchus kiensis*	Least concern	Short-line rifle cardinal
Actinopterygii	Perciformes	Apogonidae	*Pseudamia amblyuroptera*	Least concern	White-jawed cardinalfish
Actinopterygii	Perciformes	Apogonidae	*Sphaeramia orbicularis*	Least concern	Orbiculate cardinalfish
Actinopterygii	Perciformes	Apogonidae	*Yarica hyalosoma*	Least concern	Mangrove cardinalfish
Actinopterygii	Perciformes	Caesionidae	*Caesio cuning*	Least concern	Redbelly yellowtail fusilier
Actinopterygii	Perciformes	Carangidae	*Atule mate*	Least concern	Yellowtail scad
Actinopterygii	Perciformes	Ephippidae	*Platax orbicularis*	Least concern	Orbiculate batfish
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus coeruleopunctatus*	Least concern	Whitespotted grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus coioides*	Least concern	Orange-spotted grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus malabaricus*	Least concern	
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus miliaris*	Least concern	Netfin grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus polystigma*	Least concern	White-dotted grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus tauvina*	Data deficient	Greasy grouper
Actinopterygii	Perciformes	Gerreidae	*Gerres erythrourus*	Least concern	Deep-bodied mojarra

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus gibbosus*	Least concern	Brown sweetlips
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus pictus*	Least concern	Trout sweetlips
Actinopterygii	Perciformes	Haemulidae	*Pomadasys argenteus*	Least concern	Silver javelin
Actinopterygii	Perciformes	Haemulidae	*Pomadasys kaakan*	Least concern	Javelin grunter
Actinopterygii	Perciformes	Leiognathidae	*Gazza minuta*	Least concern	Toothed ponyfish
Actinopterygii	Perciformes	Leiognathidae	*Leiognathus equulus*	Least concern	Common ponyfish
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus harak*	Least concern	Thumbprint emperor
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus nebulosus*	Least concern	Spangled emperor
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus ornatus*	Least concern	Ornate emperor
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus semicinctus*	Least concern	Black-spot emperor
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulviflamma*	Least concern	Dory snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulvus*	Least concern	Blacktail snapper
Actinopterygii	Perciformes	Microdesmidae	*Parioglossus formosus*	Least concern	
Actinopterygii	Perciformes	Microdesmidae	*Parioglossus lineatus*	Data deficient	
Actinopterygii	Perciformes	Microdesmidae	*Parioglossus palustris*	Least concern	
Actinopterygii	Perciformes	Microdesmidae	*Parioglossus rainfordi*	Least concern	
Actinopterygii	Perciformes	Microdesmidae	*Parioglossus raoi*	Least concern	Yellow dartfish
Actinopterygii	Perciformes	Mullidae	*Parupeneus barberinus*	Least concern	Dash-and-dot goatfish
Actinopterygii	Perciformes	Nemipteridae	*Scolopsis ciliata*	Least concern	Saw-jawed monocle bream
Actinopterygii	Perciformes	Pomacentridae	*Dascyllus trimaculatus*	Least concern	Threespot damselfish
Actinopterygii	Perciformes	Pomacentridae	*Dischistodus perspicillatus*	Least concern	White damsel
Actinopterygii	Perciformes	Pomacentridae	*Dischistodus pseudochrysopoecilus*	Least concern	Monarch damsel
Actinopterygii	Perciformes	Pomacentridae	*Neopomacentrus azysron*	Least concern	Yellowtail damsel
Actinopterygii	Perciformes	Pomacentridae	*Neopomacentrus taeniurus*	Data deficient	Freshwater damsel
Actinopterygii	Perciformes	Sciaenidae	*Nibea coibor*	Data deficient	
Actinopterygii	Perciformes	Siganidae	*Siganus guttatus*	Least concern	Golden rabbitfish
Actinopterygii	Perciformes	Siganidae	*Siganus vermiculatus*	Least concern	Vermiculated spinefoot
Actinopterygii	Perciformes	Terapontidae	*Mesopristes cancellatus*	Least concern	Tapiroid grunter
Actinopterygii	Pleuronectiformes	Cynoglossidae	*Cynoglossus abbreviatus*	Data deficient	Three-lined tongue sole
Actinopterygii	Pleuronectiformes	Cynoglossidae	*Cynoglossus puncticeps*	Least concern	

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Pleuronectiformes	Cynoglossidae	*Cynoglossus sibogae*	Data deficient	
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Pseudorhombus arsius*	Least concern	Largetooth flounder
Actinopterygii	Pleuronectiformes	Soleidae	*Brachirus aspilos*	Least concern	Dusky sole
Actinopterygii	Pleuronectiformes	Soleidae	*Rhinosolea microlepidota*	Data deficient	
Actinopterygii	Scorpaeniformes	Platycephalidae	*Cymbacephalus beauforti*	Least concern	Crocodile fish
Actinopterygii	Syngnathiformes	Syngnathidae	*Hippichthys penicillus*	Least concern	Beady pipefish
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron manilensis*	Least concern	Narrow-lined puffer
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron reticularis*	Least concern	Reticulated pufferfish
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron stellatus*	Least concern	Stellate puffer
Aves	Charadriiformes	Charadriidae	*Charadrius mongolus*	Least concern	Lesser sandplover
Aves	Charadriiformes	Charadriidae	*Pluvialis fulva*	Least concern	Pacific golden plover
Aves	Charadriiformes	Scolopacidae	*Actitis hypoleucos*	Least concern	Common sandpiper
Aves	Charadriiformes	Scolopacidae	*Numenius arquata*	Near threatened	Eurasian curlew
Aves	Coraciiformes	Alcedinidae	*Alcedo atthis*	Least concern	Common kingfisher
Aves	Coraciiformes	Alcedinidae	*Halcyon coromanda*	Least concern	Ruddy kingfisher
Aves	Coraciiformes	Alcedinidae	*Todiramphus chloris*	Least concern	Collared kingfisher
Aves	Galliformes	Megapodiidae	*Megapodius cumingii*	Least concern	Philippine scrubfowl
Aves	Passeriformes	Campephagidae	*Lalage nigra*	Least concern	Pied triller
Aves	Passeriformes	Campephagidae	*Pericrocotus divaricatus*	Least concern	Ashy minivet
Aves	Passeriformes	Campephagidae	*Pericrocotus tegimae*	Least concern	Ryukyu minivet
Aves	Passeriformes	Corvidae	*Corvus enca*	Least concern	Slender-billed crow
Aves	Passeriformes	Corvidae	*Corvus macrorhynchos*	Least concern	Large-billed crow
Aves	Passeriformes	Monarchidae	*Terpsiphone atrocaudata*	Near threatened	Japanese paradise-flycatcher
Aves	Passeriformes	Muscicapidae	*Cyornis rufigastra*	Least concern	Mangrove blue-flycatcher
Aves	Passeriformes	Paridae	*Parus major*	Least concern	Great tit
Aves	Passeriformes	Phylloscopidae	*Phylloscopus coronatus*	Least concern	Eastern crowned warbler
Aves	Passeriformes	Sturnidae	*Aplonis panayensis*	Least concern	Asian glossy starling
Aves	Passeriformes	Turdidae	*Turdus obscurus*	Least concern	Eyebrowed thrush
Aves	Pelecaniformes	Ardeidae	*Ardea purpurea*	Least concern	Purple heron

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Pelecaniformes	Ardeidae	*Butorides striata*	Least concern	Green-backed heron
Aves	Pelecaniformes	Ardeidae	*Egretta eulophotes*	Vulnerable	Chinese egret
Aves	Pelecaniformes	Ardeidae	*Egretta garzetta*	Least concern	Little egret
Aves	Pelecaniformes	Ardeidae	*Egretta sacra*	Least concern	Pacific reef-egret
Aves	Pelecaniformes	Ardeidae	*Ixobrychus cinnamomeus*	Least concern	Cinnamon bittern
Aves	Pelecaniformes	Ardeidae	*Ixobrychus sinensis*	Least concern	Yellow bittern
Aves	Suliformes	Anhingidae	*Anhinga melanogaster*	Near threatened	Oriental darter
Aves	Suliformes	Fregatidae	*Fregata ariel*	Least concern	Lesser frigatebird
Aves	Suliformes	Fregatidae	*Fregata minor*	Least concern	Great frigatebird
Bivalvia	Venerida	Cyrenidae	*Polymesoda bengalensis*	Least concern	Bengali geloina
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus amblyrhynchoides*	Vulnerable	Graceful shark
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus amboinensis*	Vulnerable	Pigeye shark
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus melanopterus*	Vulnerable	Blacktip reef shark
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Negaprion acutidens*	Endangered	Sharptooth lemon shark
Chondrichthyes	Myliobatiformes	Dasyatidae	*Himantura leoparda*	Vulnerable	Leopard whipray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Himantura uarnak*	Endangered	Coach whipray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Maculabatis macrura*	Endangered	Sharpnose whipray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Pastinachus ater*	Vulnerable	Broad cowtail ray
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis zijsron*	Critically endangered	Green sawfish
Gastropoda	Cycloneritida	Neritidae	*Clithon faba*	Least concern	Kanokogai
Gastropoda	Cycloneritida	Neritidae	*Neritodryas subsulcata*	Data deficient	Weakly cut nerite
Gastropoda	Ellobiida	Ellobiidae	*Auriculastra elongata*	Least concern	
Gastropoda	Ellobiida	Ellobiidae	*Auriculastra subula*	Least concern	
Gastropoda	Ellobiida	Ellobiidae	*Cassidula crassiuscula*	Least concern	
Gastropoda	Ellobiida	Ellobiidae	*Cassidula multiplicata*	Least concern	
Gastropoda	Ellobiida	Ellobiidae	*Cylindrotis quadrasi*	Least concern	
Gastropoda	Ellobiida	Ellobiidae	*Laemodonta bella*	Least concern	
Gastropoda	Ellobiida	Ellobiidae	*Laemodonta punctigera*	Least concern	
Gastropoda	Ellobiida	Ellobiidae	*Melampus sulculosus*	Least concern	
Gastropoda	Littorinimorpha	Clenchiellidae	*Clenchiella microscopica*	Least concern	
Gastropoda	Littorinimorpha	Littorinidae	*Littoraria undulata*	Least concern	

Class	Order	Family	Scientific name	RLTS category	Common name
Gastropoda	Neogastropoda	Conidae	*Conus frigidus*	Least concern	Frigid cone
Gastropoda	Neogastropoda	Conidae	*Conus furvus*	Least concern	
Gastropoda	Neogastropoda	Conidae	*Conus insculptus*	Least concern	
Gastropoda	Neogastropoda	Conidae	*Conus varius*	Least concern	
Gastropoda	Sorbeoconcha	Potamididae	*Cerithidea ornata*	Least concern	
Gastropoda	Sorbeoconcha	Thiaridae	*Sermyla riqueti*	Least concern	
Insecta	Odonata	Coenagrionidae	*Ceriagrion cerinorubellum*	Least concern	
Magnoliopsida	Fabales	Fabaceae	*Dalbergia candenatensis*	Least concern	Trắc một hột
Magnoliopsida	Lamiales	Acanthaceae	*Acanthus ebracteatus*	Least concern	
Magnoliopsida	Malvales	Malvaceae	*Brownlowia argentata*	Data deficient	
Magnoliopsida	Malvales	Malvaceae	*Brownlowia tersa*	Near threatened	
Magnoliopsida	Malvales	Malvaceae	*Heritiera littoralis*	Least concern	
Magnoliopsida	Myrtales	Lythraceae	*Pemphis acidula*	Least concern	
Mammalia	Carnivora	Felidae	*Prionailurus bengalensis*	Least concern	Mainland leopard cat
Mammalia	Cetartiodactyla	Phocoenidae	*Neophocaena asiaeorientalis*	Endangered	Narrow-ridged finless porpoise
Mammalia	Cetartiodactyla	Suidae	*Sus scrofa*	Least concern	Wild boar
Mammalia	Chiroptera	Pteropodidae	*Pteropus dasymallus*	Vulnerable	Ryukyu flying fox
Mammalia	Sirenia	Dugongidae	*Dugong dugon*	Vulnerable	Dugong
Reptilia	Squamata	Scincidae	*Emoia atrocostata*	Least concern	Littoral whiptail-skink

3. National Estimates for Subcriterion A1

To estimate the South Kuroshio mangrove ecosystem extent in 1970, we gathered reliable information on the mangrove area for each country within the province that can be used for an extrapolation (Table b). There are mangrove area estimates for Okinawa Prefecture in 1977 and 1997 based on aerial photo analysis with ground truth data (ISME, 2004; Inoue *et al*., 2022a). The mangrove areas in Okinawa Prefecture are equivalent to ~90% of the entire mangrove area of South Kuroshio. In addition to these datasets, we added estimates for 2020 based on satellite image analysis (mostly the same method as ISME, 2004) on mangrove areas of Okinawa Prefecture. We then estimated the mangrove area in 1970 for this province, assuming a linear relationship between mangrove extent and time (Table a). Using mangrove area estimates from different sources can lead to uncertainty (Friess and Webb 2014)[2] and there were no regional statistics or

[2] Friess, D. A., & Webb, E. L. (2014). Variability in mangrove change estimates and implications for the assessment of ecosystem service provision: Variability in mangrove ecosystem loss. *Global Ecology and Biogeography*, *23*(7), 715–725. https://doi.org/10.1111/geb.12140

global studies available for this time period. Thus, the estimates for 1970 should be considered only indicative.

Table a. Estimated mangrove area (km^2) by country in 1970 and 2020. Estimates for 2020* mangrove area in Calayan Island are based on the Global Mangrove Watch Version 3 (GMW v3.0) dataset and area in Okinawa Prefecture are based on the newly assessed data in this report. The references used to calculate mangrove area in 1970 are listed below in Table b.**

Year	Country total 2020*	Within province 2020*	Country total 1970**	Within province 1970**
Okinawa prefecture (Japan)	7.3	7.3	5.1	5.1
Calayan Island (Philippines)		0.09	dd	dd
The South Kuroshio		**7.4**		**5.1**

dd: data deficient

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 Kuroshio province.

Country	Year	Mangrove Area (ha)	Reference
Japan	1980	400	Nakasuga (1980). Personal communication Cited in: Snedaker, S.C. 1984. The mangroves of Asia and Oceania: status and research planning. In: Proceedings of the Asian Mangrove Symposium, eds: Soepadmo, E Rao, AN; McIntosh, DJ. p. 5-15. Percetakan Ardyas Sdn Bhd. Kuala Lumpur, 25-29 August 1980, Kuala Lumpur, Malaysia. Expert estimate.
Japan (Okinawa)	1977	540.1	ISME (2004). Mangrove distribution survey in Okinawa prefecture for the purpose of monitoring coastal ecosystems and sea level rise. Okinawa prefecture commissioned survey research in fiscal year 2003. International Society for Mangrove Ecosystems, Okinawa, p 153.
Japan (Okinawa)	1997	643.5	ISME (2004). Mangrove distribution survey in Okinawa prefecture for the purpose of monitoring coastal ecosystems and sea level rise. Okinawa prefecture commissioned survey research in fiscal year 2003. International Society for Mangrove Ecosystems, Okinawa, p 153.
Japan (Okinawa)	2020	730.9	This assessment
Japan (Kagoshima)	2020	66.1	This assessment
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.