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Mangroves of the Central Pacific EN

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Abstract

The Central Pacific mangrove province is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology) including the marine ecoregions of the Gilbert/Ellis Islands, Marshall Islands, Phoenix/Tokelau/Northern Cook Islands, and Samoa Islands. The Central Pacific mangroves had a mapped extent in 2020 of 4.8 km^2, representing less than 0.01% of the global mangrove area. The biota is characterized by 7 species of true mangroves, and 77 associate animals are listed on the Red List of Threatened Species (RLTS) database.

While the Central Pacific islands have relatively small mangrove areas, mangroves provide a critical contribution to remote island biodiversity, and provide ecosystem benefits to adjacent corals and seagrass systems. Geomorphic settings of mangrove ecosystems include lagoonal fringes of calcareous atolls, small estuaries of Samoa, American Samoa and Wallis, and inland mangrove ponds separated from the coast that are extremely rare globally. Threats recorded include mangrove vegetation clearance and conversion, solid waste, unsustainable exploitation of mangrove wood and crabs, sand mining and erosion causing mangrove dieback, contaminated wastewater runoff and agricultural fertilisers.

The Central Pacific mangroves are Data Deficient for the majority of IUCN ecosystem classification assessment criteria, reflecting lack of on-ground mangrove research and lack of historical spatial imagery. While information available indicates mangrove net area change of -0.5% since 1996, higher resolution spatial analysis is needed. Furthermore, under a high sea level rise scenario (IPCC RCP8.5) ≈-50.8% of the Central Pacific mangroves would be submerged by 2060. Relative sea level rise trends are higher than those globally recorded owing to vertical land movement subsidence, data indicating that +1.5-2.0 mm/year should be added to the IPCC projected rates. Overall, the Central Pacific mangrove ecosystem is assessed as **Endangered (EN).**

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

Ecosystem classification
MFT1.2 Intertidal forests and shrublands
Assessment's distribution:
Central Pacific province
Summary of the assessment:

Criterion	A	B	C	D	E	Overall
Subcriterion 1	**DD**	**LC**	**DD**	**DD**	**NE**	
Subcriterion 2	**DD**	**VU**	**EN**	**DD**	**NE**	**EN**
Subcriterion 3	**DD**	**DD**	**DD**	**DD**	**NE**	

EN: Endangered, VU: Vulnerable,
LC: Least Concern, DD Data Deficient, NE: Not Evaluated

Mangroves of the Central Pacific EN

1. Ecosystem Classification

IUCN Global Ecosystem Typology (version 2.1, Keith *et al.*, 2022):

Transitional Marine-Freshwater-Terrestrial realm

MFT1 Brackish tidal biome

MFT1.2 Intertidal forests and shrublands

MFT1.2_4_MP_38x Mangroves of the Central Pacific

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]

5 Wetlands (inland)

5.18. Wetlands (inland) – Karst and other subterranean hydrological systems (inland)

12 Marine Intertidal

12.7 Mangrove Submerged Roots

[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.

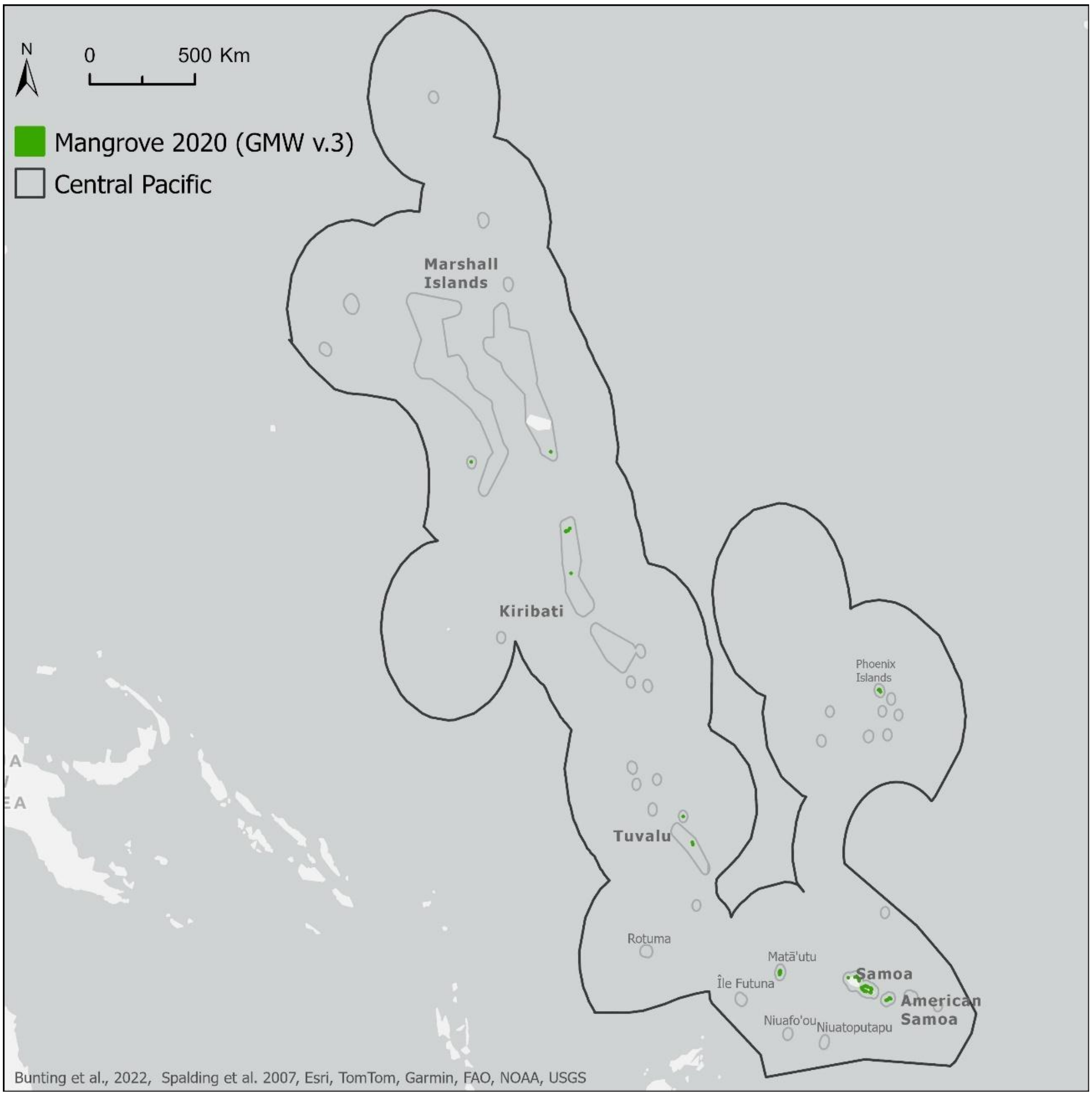


Figure 1. The mangroves of Central Pacific province.

2. Ecosystem Description

Spatial distribution

The mangroves of the Central Pacific province include intertidal forests and shrublands of the marine ecoregions of the Marshall Islands, Gilbert/Ellis Islands, and all islands of the Samoa group. This province also includes the eastern Phoenix/Tokelau/Northern Cook Islands; however these lack true mangroves (Spalding *et al*., 2010). The countries and territories included are the Republic of the Marshall Islands, the Republic of Kiribati, Tuvalu, the northern islands of the Republic of Fiji, French collectivité d'outre-mer of Wallis and Futuna, the Independent State of Samoa, and American Samoa, the unincorporated territory of the United States of America (Figure 1).

The estimated extent of mangroves in this province was about 4.8 km^2 in 2020, representing <0.01% of the global mangrove area. Larger areas occur in Samoa, with 2.07 km^2 mapped in 2012-2013 across the three largest mangrove areas (Siamomua-Momoemausu, 2013), out of Samoa's at least 17 mangrove areas. American Samoa has recorded 0.52 km^2 (Spalding *et al*., 2010), and Wallis 0.33 km^2 (Trégarot *et al*., 2021).

In the Marshall Islands, mangroves occur on southern atolls with heavier rainfall: Jaluit, Namdrik and Ailinglapalap, and further north in inland ponds (Goldstein and DellaSala, 2020). The most easterly occurrence is on Kanton atoll, of the Line Islands in Kiribati, where 0.39 km^2 of mangroves have been mapped (Forstreuter and Bataua, 2011). In Tuvalu, inland mangroves occur as land-locked lagoons or pond depressions on Niutao and Nanumanga (Woodroffe 1987; Spalding *et al*., 2010).

There has been a -0.5 % net area change since 1996 (Bunting *et al.*, 2022), with positive mangrove area gain recorded for protected wetlands such as No'oto Ramsar site in Kiribati (Ellison *et al*., 2017) and Jaluit Ramsar site in the Marshall Islands (Crameri and Ellison, 2022). Spatial analysis from American Samoa showed seaward edge retreat at the three largest mangrove areas 1961-2004 (Gilman *et al*., 2007a), but subsequently the mangrove cover has been stable at 0.32 km^2 (Bunting *et al*., 2022).

Biotic components of the ecosystem (characteristic native biota)

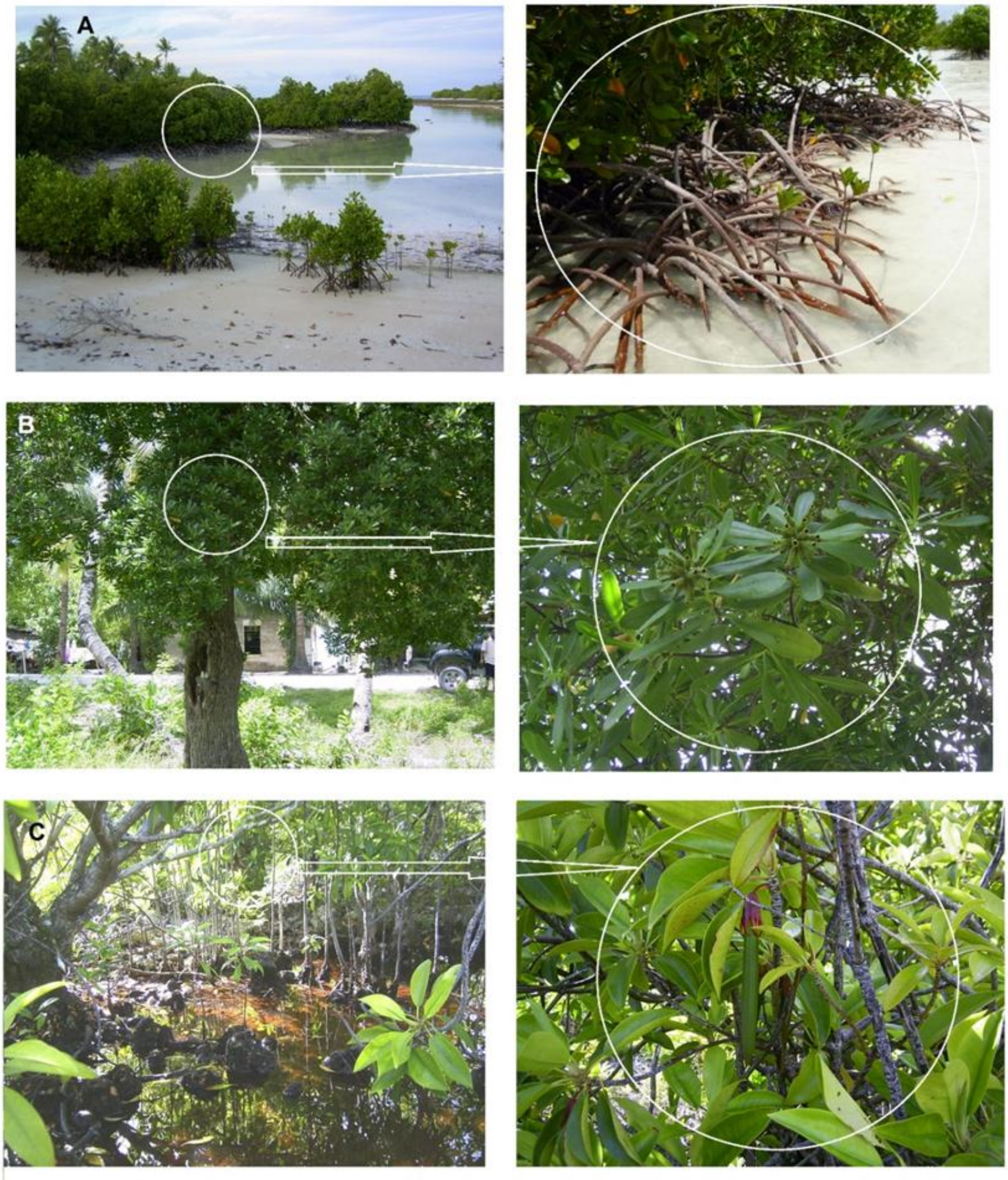
The mangroves of the Central Pacific province have unique diversity with seven recorded true mangrove plant species (IUCN, 2022). Each island group has different combinations of these species, causing ecosystem structure to be unique for each (Ellison, 2009). Mangroves disperse by propagule flotation, and island remoteness causes population isolation, hence the eastern limit of mangroves is through Kiribati, and east of Tuvalu and American Samoa. True mangroves do not extend to Tuamotu and the Cook Islands (Bhattari and Giri, 2011), although the mangrove associate *Pemphis acidula* occurs commonly on rock shores, as well as throughout the Central Pacific province. There are at least 77 animal species within seven classes associated with mangrove habitats in the IUCN Red List of Threatened Species (IUCN, 2022) that have natural history collection records, or observations, within the distribution of this province (GBIF, 2022). For example, 31 fisheries species were recorded offshore from the mangroves of Le Asaga Island in Samoa (Siamomua-Momoemausu, 2013).

Abiotic Components of the Ecosystem

The geomorphic settings of mangroves in the province are very varied, including calcareous atolls of the Marshall Islands, Tuvalu and Kiribati, small estuaries of the Samoan high islands; fringing mangroves on the most sheltered shorelines; and inland ponded mangroves that are rare globally. Many mangrove substrata are lower in nutrients, especially nitrogen and phosphorus, relative to the large mangrove areas in Asia, but studies in this province are very limited. Regional species distributions are also influenced by rainfall, hydrology, sea level, sediment dynamics, subsidence, storm-driven processes, and disturbance. Rainfall and sediment supply from rivers are limited to high islands, and most mangrove settings are marine-dominated, causing mangrove stature to be smaller relative to estuarine settings. Currents promote mangrove establishment and provide sediment supply, while waves and large tidal currents can destabilise and erode soft mangrove substrata, mediating local-scale dynamics in ecosystem distributions. Sediment supply on low islands includes high proportions of calcareous biotic production from adjacent reefs and seagrass beds (Ellison *et al*., 2019).

Fringing mangroves at Tutuila in American Samoa, indicating small catchment sizes of the Central Pacific high islands (Photo credit: Joanna Ellison)

While the mangrove area is small relative to global extents, owing to the small size of land area of these islands, the mangroves are a critical contribution to remote island biodiversity, and provide ecosystem benefits to adjacent corals and seagrass systems. Furthermore, unusual inland mangroves are frequent in the Central Pacific, as enclosed lagoons or ponds on limestone islands or atolls (Woodroffe, 1987; Ellison, 2009; Ellison, 2019; Crameri and Ellison, 2022). These are genetically isolated and sustained by groundwater levels and low competition, so vulnerable to dry conditions and disturbance. Some have become limited to just a couple of trees and are being encroached by land-use changes.



Mangroves of the Central Pacific province, with close-ups horizontally. A) Fringing mangroves of Rhizophora stylosa in North Tarawa, Kiribati, illustrating small stature Rhizophora growing in full salinity with aerial roots allowing high tide respiration and stability. All atoll islands are <2 m in elevation and lack rivers. B) Inland occurrence of Lumnitzera littorea, South Tarawa, Kiribati, showing waxy leaves to conserve water as well as issues of urban encroachment. C) An inland rock-enclosed pond of Bruguiera gymnorhiza in Ailuk atoll, Republic of the Marshall Islands, showing viviparous propagules (Photo credit: Joanna Ellison)

Key processes and interactions

Mangroves of the Central Pacific islands are important for coastal protection from waves and during storms, particularly the destructive winds and storm surges associated with tropical cyclones. These values are recognised with high confidence by the Intergovernmental Panel on Climate Change (Hoegh-Guldberg *et al*., 2018). Mangrove values extend to provision of fish and crabs for food, and wood for building construction and fuel (Figure 2). Fish is the primary food source for Pacific islands people (Charlton *et al*., 2016), with reliable fish supplies essential to regional food security. Islands are small, with human populations concentrated on the coast. Annual monetary value of mangroves of Wallis are estimated at 33,257 ±16,861 Euros (Trégarot *et al*., 2021), with 3906 ±552 kg/ year fish biomass production. Community surveys from Samoa also found that mangroves provide people's sense of belonging to cultural heritage, identity and place (Fuller *et al*., 2022).

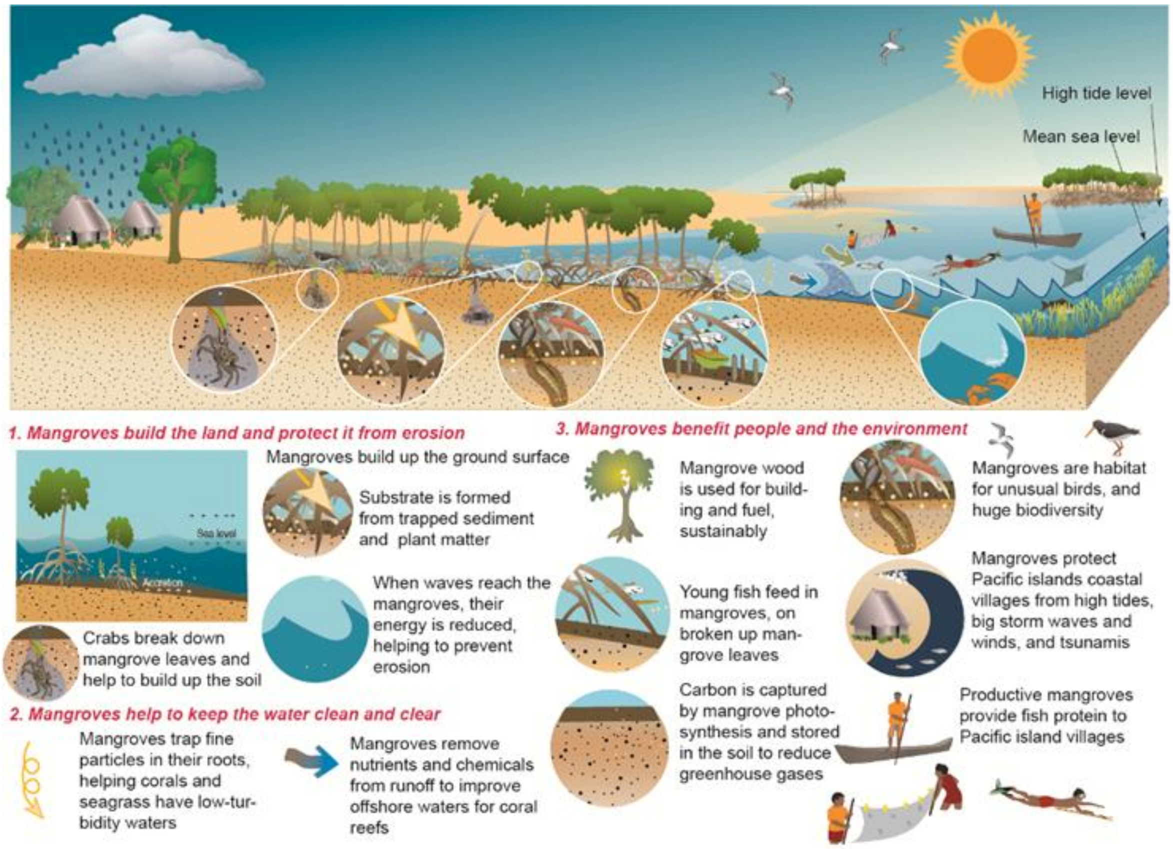


Figure 2. Mangrove zonation typical of the Central Pacific, with *Rhizophora sp.* Seaward and *Bruguiera gymnorhiza* landward. This conceptual diagram summarises the ecosystem settings and mangrove values in the region *(image by Jan Tilden, Michael Helman and Joanna Ellison)*.

Mangroves act as structural engineers possessing traits such as aerial roots, (salt excretion glands, waxy leaves, 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, though studies on the Central Pacific mangroves are few. Mangroves produce large amounts of detritus (e.g., leaves, twigs, and bark), which is either buried in waterlogged sediments, or consumed by crabs and gastropods, and then decomposed further by meiofauna, fungi and bacteria, thus mobilising carbon, and nutrients to other consumers in the mangrove and coastal food web such as fish. Mangrove wetlands also serve as major blue carbon sinks, incorporating organic matter into biomass and sediments through organic matter deposition and root mats (Figure 3).

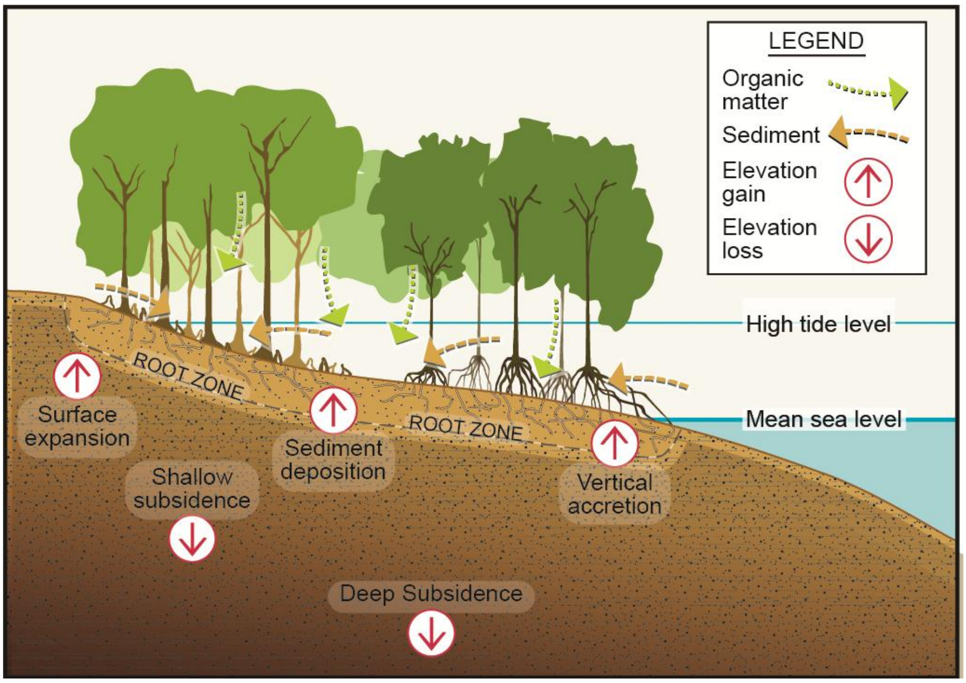


Figure 3. Conceptual diagram showing carbon sequestration processes in mangroves: above-ground biomass accumulation, below-ground root mat development, organic sediment deposition, and vertical accretion and subsidence processes (Ellison 2019).

Carbon sequestration by mangroves in the Central Pacific has potential to offset large proportions of each nation’s emissions from agriculture, forestry and other land uses (Friess, 2023). Mangrove above-ground carbon sequestration for Samoan mangroves of 4-11 m height was evaluated to have a biomass of 188-520 tonnes/ hectare (Siamomua-Momoemausu, 2013). No research is available for other mangroves in the province, or for any below-ground carbon sequestration rates.

3. Ecosystem Threats and vulnerabilities

Main threatening process and pathways to degradation

Direct threats to mangroves are recorded in this province. Threats in Samoa include poor land practices such as clearing of vegetation, unsustainable exploitation of mangrove crabs, sand mining and erosion causing mangrove dieback (Siamomua-Momoemausu, 2013). Anthropogenic pressures from land conversion of mangroves on Moata’a, northern Upolu Island in Samoa caused a reduction in area from 20 ha in 1974 to 10 ha in 1990 (Jorquera *et al*., 2022), later halted by increased mangrove protection. Contamination issues include wastewater runoff and sewage leakage from urban areas, and high nutrients coming from agricultural fertilisers. A further pressure is use of mangrove wood for firewood, yet mangrove cutting has recently been banned by the local matai council (Jorquera *et al*., 2022). Threats recently recorded from American Samoa include solid waste garbage in mangroves, and heavy metals detected in locally caught fish (Lewis, 2023). Threats documented also include cutting of mangroves for firewood and boat access, impacts from catchment landuse changes, and seaward edge mangrove retreat associated with relative sea-level rise (Gilman *et al*., 2007a; Gilman *et al*., 2007b).

Cyclone or typhoon impacts on mangroves recorded in the province have been devastating at the time, but the affected mangroves have later shown effective regrowth (Siamomua-Momoemausu, 2013; Crameri and Ellison, 2022).

Micro-tidal ranges of the Central Pacific cause mangrove area flushing to be particularly vulnerable to hydrological restrictions. Poorly designed causeways disrupt flows, restricting sediment supply or causing mangrove mortality (Gillie 1997; Jorquera *et al*., 2022). Causeway connections to islands in Kiribati have disrupted currents from windward to leeward mangrove coasts, impacting mangroves through coastal erosion, alteration of lagoon circulation, freshwater diversion and inter-channel blockage (Gillie, 1997; Mangubhai *et al*., 2019). Mangroves in Kiribati are also threatened by deforestation for domestic purposes, coastal infrastructure development, and pollution (Mangubhai *et al*., 2019).

Low-lying islands, including the atolls of the Pacific, are at great risk from the impacts of climate change, particularly sea-level rise (SLR) (Hoegh-Guldberg *et al*., 2018). Satellite altimetry data 1993-2017 showed that the Central Pacific experienced rates of SLR of 3-4 mm/year, being higher towards the west (Aucan, 2018), attributed to large scale trade winds. Relative sea-level rise (RSLR) combining land vertical ground movement (VGM) is shown by the few tide gauge records in the province. RSLR at Funafuti (Tuvalu) was +4.19 ±0.70 mm/year (1977-2017) (Aucan, 2018); and at Tarawa (Kiribati) it was 3.41 ±0.83 (1974-2017). In the Marshall Islands, RSLR at Majuro was 3.53 ±1.8 (1969-2019) and at Kwajalein 1.98 ±0.65 (1946-2020) (Crameri and Ellison, 2022). Variability also occurs owing to fluctuations of the El Niño-Southern Oscillation (ENSO), as evident in interannual trends, causing higher sea-level for months or more that would lead to inundation stress on mangroves. To the west, a survey of mangroves in Pohnpei showed that mangroves occupy 75% of the tidal range, and this is likely related to ENSO variability (Ellison *et al*., 2022).

VGM contributes to relative sea-level rise by subsidence, Darwin’s interpretation of atoll formation from volcanic island growth and oceanic tectonic plate loading confirmed by dated deep stratigraphy (Ohde *et al*., 2002). Recent trends from GPS measurements showed atolls of Tarawa (Kiribati) to have a VGM of -2.2 ±0.24 mm /year, and Funafiti (Tuvalu) -1.71 ±0.17 mm/ year (Aucan, 2018). Subsidence combined with climate-change induced global sea-level rise will increase the potential stress on mangroves in the Central Pacific. The VGM data indicate that +1.5-2.0 mm/year should be added to the IPCC projected rates of SLR 4.1 (2.8–6.0) to 7.2 (5.6–9.7) mm/year by 2040-2060 (Fox-Kemper *et al*., 2021).

Mangrove surface accretion is needed to maintain mangrove inundation preferences relative to RSLR, otherwise their inland migration is necessitated (Ellison *et al*., 2022). Sediment supply for high islands such as Wallis and Futuna, and the Samoa islands can include fluvial minerogenic sediment, but the atolls of Kiribati, Tuvalu and the Marshall Islands lack rivers hence mangrove sediments are derived from coral reef debris and associated molluscs, calcareous algae and foraminifera (Ellison *et al*., 2019). Healthy mangroves also contribute to accretion through root mat development (McKee, 2011) and organic matter retention.

Mangrove loss arises from various factors in the Central Pacific, including coastal conversion and infill, urbanization expansion, associated coastal development, over-harvesting, blocking of tidal flows, and pollution stemming from domestic, industrial, municipal rubbish tips, and agricultural land use, particularly adjacent to urban centres (Veitayaki *et al*., 2017).

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% mortality).

Mangrove 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. In the Central Pacific province, as each individual mangrove area is small and isolated from others by ocean distances between island groups, or rock headlands between bays of fringing mangroves, mangrove vulnerability or loss without the capacity to recover is therefore high relative to continental mangroves.

Ecosystem collapse may manifest through the following mechanisms: a) restricted recruitment and survival of diagnostic true mangroves due to adverse climatic conditions (e.g., drought or higher RSL owing to ENSOs); b) alterations in rainfall, river inputs, waves, and tidal currents that destabilize and erode substrata, hindering recruitment and growth; c) shifts in rainfall patterns and tidal flushing altering salinity stress and nutrient loadings, impacting mangrove survival.

In the Central Pacific province, mangrove ecosystem collapse has manifested by seaward edge mangroves showing stress, followed by mortality, unsuccessful recruitment and spatial evidence of retreat (Gilman *et al*., 2007a). Monitoring evidence would show reduction in mangrove tree density and biomass, unsuccessful recruitment, and poor net substratum sediment accretion. Landward mangroves have shown ecosystem collapse following mangrove clearance and infill. Data from this province is however limited, indicating the need for investment in ecosystem monitoring, including sedimentation dynamics.

Examples of decline and collapse of Central Pacific mangroves: A) American Samoa seaward edge showing stress and mortality; B) American Samoa cleared mangrove area; C) Mangrove landward edge tree cutting and infills; D) Kiribati stressed seaward edge mangroves (Photo credits: Joanna Ellison)

Threat Classification

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

1. Residential & commercial development

- 1.1 Housing & urban areas
- 1.2 Commercial & industrial areas
- 1.3 Tourism & recreation areas

2. Agriculture & aquaculture

- 2.1 Annual & perennial non-timber crops
    - 2.1.1 Shifting agriculture
    - 2.1.2 Small-holder farming
    - 2.1.4 Scale Unknown/Unrecorded
    - 2.2.1 Small-holder plantations
    - 2.2.3 Scale Unknown/Unrecorded
    - 2.3.4 Scale Unknown/Unrecorded
- 2.4 Marine & freshwater aquaculture
    - 2.4.1 Subsistence/artisanal aquaculture
    - 2.4.3 Scale Unknown/Unrecorded

3. Energy production & mining

- 3.2 Mining & quarrying
- 3.3 Renewable energy

4. Transportation & service corridors

- 4.1 Roads & railroads
- 4.2 Utility & service lines

5. Biological resource use

- 5.1 Hunting & collecting terrestrial animals
    - 5.1.1 Intentional use (species being assessed is the target)
    - 5.1.2 Unintentional effects (species being assessed is not the target)
- 5.2 Gathering terrestrial plants
    - 5.2.1 Intentional use (species being assessed is the target)
    - 5.2.2 Unintentional effects (species being assessed is not the target)
    - 5.2.4 Motivation Unknown/Unrecorded
- 5.3 Logging & wood harvesting
    - 5.3.1 Intentional use: subsistence/small scale (species being assessed is the target [harvest]
    - 5.3.2 Intentional use: large scale (species being assessed is the target)[harvest]
    - 5.3.3 Unintentional effects: subsistence/small scale (species being assessed is not the target)[harvest]
    - 5.3.4 Unintentional effects: large scale (species being assessed is not the target)[harvest]
    - 5.3.5 Motivation Unknown/Unrecorded
- 5.4 Fishing & harvesting aquatic resources
    - 5.4.1 Intentional use: subsistence/small scale (species being assessed is the target)[harvest]
    - 5.4.2 Intentional use: large scale (species being assessed is the target)[harvest]
    - 5.4.3 Unintentional effects: subsistence/small scale (species being assessed is not the target)[harvest]
    - 5.4.4 Unintentional effects: large scale (species being assessed is not the target)[harvest]
    - 5.4.6 Motivation Unknown/Unrecorded

6. Human intrusions & disturbance

- 6.1 Recreational activities
- 6.3 Work & other activities

7. Natural system modifications

- 7.1 Fire & fire suppression
    - 7.1.3 Trend Unknown/Unrecorded
- 7.2 Dams & water management/use
    - 7.2.1 Abstraction of surface water (domestic use)
    - 7.2.2 Abstraction of surface water (commercial use)
    - 7.2.3 Abstraction of surface water (agricultural use)
    - 7.2.4 Abstraction of surface water (unknown use)
    - 7.2.5 Abstraction of ground water (domestic use)
    - 7.2.6 Abstraction of ground water (commercial use)
    - 7.2.7 Abstraction of ground water (agricultural use)
    - 7.2.8 Abstraction of ground water (unknown use)
    - 7.2.9 Small dams
- 7.3 Other ecosystem modifications

8. Invasive & other problematic species, genes & diseases

- 8.1 Invasive non-native/alien species/diseases
    - 8.1.1 Unspecified species
- 8.2 Problematic native species/diseases
    - 8.2.1 Unspecified species

    - 8.2.2 Named species
- 8.3 Introduced genetic material
- 8.4 Problematic species/diseases of unknown origin
    - 8.4.1 Unspecified species
    - 8.4.2 Named species

9. Pollution

- 9.1 Domestic & urban waste water
    - 9.1.1 Sewage
    - 9.1.2 Run-off
    - 9.1.3 Type Unknown/Unrecorded
- 9.2 Industrial & military effluents
    - 9.2.1 Oil spills
    - 9.2.3 Type Unknown/Unrecorded
- 9.3 Agricultural & forestry effluents
    - 9.3.1 Nutrient loads
    - 9.3.2 Soil erosion, sedimentation
    - 9.3.3 Herbicides & pesticides
    - 9.3.4 Type Unknown/Unrecorded
- 9.4 Garbage & solid waste

10. Geological events

- 10.1 Volcanoes
- 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

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. Furthermore, country-level estimates of mangrove extent can be used to extrapolate the trend between 1970 and 2020 but in this case there no available data for the last 50 years and the Central Pacific is considered as Data Deficient (DD) for subcriterion A1.

Subcriterion A2 measures the change in ecosystem extent in any 50-year period, including from the present to the future: In this case, to estimate the Central 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).

The Central Pacific province mangroves show a net area change of -0.5% (1996-2020) based on the Global Mangrove Watch time series (Bunting *et al.*, 2022). This value reflects the offset between areas gained (+ 0.1%/year) and lost (- 0.1%/year). However, owing to the small scales of many Central Pacific mangroves, higher resolution spatial analyses are needed (Crameri and Ellison, 2022). Generation of a new baseline dataset for 2020 from 10 m Sentinel-2 optical data. Sentinel-2 optical data are expected to improve the spatial detail of the baseline and allow better detection of mangroves that occur as narrow strips (Bunting *et al*. 2022). Therefore, it is not possible to use this dataset to assess criteria A2 and the Central Pacific is considered as **Data Deficient (DD)** for 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 Central Pacific mangrove ecosystem is classified as **Data Deficient (DD)** for this subcriterion.

Overall, the ecosystem is assessed as **Data Deficient (DD) under** criterion A.

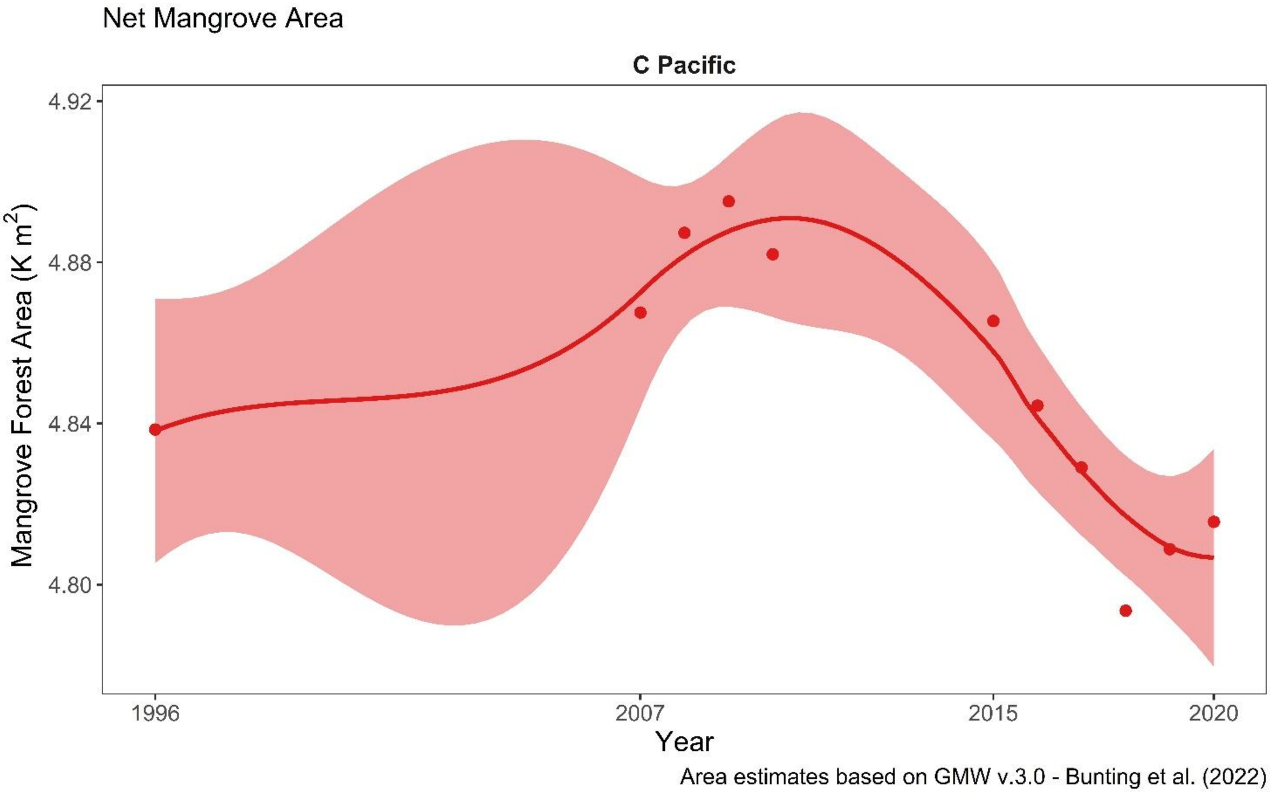


Figure 4. The Central Pacific mangrove ecosystem extent from1996 to 2020. Circles represent the province mangrove area between 1996 and 2020 based on the GMW v3.0 dataset and equation in Bunting *et al.*, (2022). The solid line and shaded area are the linear regression and 95% confidence intervals.

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) (Gaston and Fuller, 2009). These parameters were calculated based on the 2020 Central Pacific province mangrove extent (GMW v.3).

Province	Extent of Occurrence EOO (km^2)	Area of Occupancy (AOO ≥ 1% Ecosystem Area)	Criterion B
The Central Pacific	2261966.8	31	**VU**

For 2020, AOO and EOO were measured as 31 grid cells 10 x 10 km and 2261966.8 km^2, respectively (Figure 5). Excluding from total of 40 those grid cells that contain patches of mangrove forest that account for less than 1% of the ecosystem area (< 0.048 km^2), **the AOO is measured as 31, 10 x 10 km grid cells** (Figure 5).

Subcriterion B1 measures the EOO, which captures the overall geographic spread of the localities at which the ecosystem occurs, rather than the area over which it is actually found (Gaston and Fuller, 2009). Referring to Guidelines of Bland *et al.* (2017), separation of habitats spreads risk across the ecosystem from direct threats, and risks from RSLR are at present not justified at 90-100% probability. Therefore, the Central Pacific mangrove ecosystem is considered **Least Concern (LC)** for this subcriterion.

Subcriterion B2 measures the AOO or spread of risk among occupied patches of ecosystem (Bland *et al*., 2017), providing a general measure of how robust the distribution will be to stochastic and directional threatening processes, and of the relative population sizes of species (Gaston and Fuller, 2009). The Central Pacific region's mangroves are limited in overall area, and each individual mangrove area is small and isolated from others by ocean distances between island groups or rock headland confinement between bays of fringing mangroves. Many estuarine mangroves of the Samoa islands are confined inside restricted entrances. Direct anthropogenic threats classified above are documented in terms of land use change and unsustainable use of mangrove resources, while other threats such as invasive species are not determined owing to limited studies available from the Central Pacific. All occurrences of the ecosystem in the province are below the grain size of standard methods for assessment for AOO (Bland *et al*., 2017). Mangroves of the province are critically endangered owing to higher RSLR compared with other regions, and low sediment supplies to restrict potential mangrove substratum accretion. These factors combine to justify a **Vulnerable (VU)** category for B2 Restricted geographic distribution.

Subcriterion B3 uses qualitative information on the distribution of the ecosystem and threats to its persistence (Bland *et al*., 2017), and needs site-based information regarding threats that is not available for many mangrove locations in the province to date. This justifies a **Data Deficient (DD)** category for subcriterion B3. As a result from consideration of the subcriteria B1, B2 and B3, the Central Pacific mangrove ecosystem is assessed as **Vulnerable (VU)** under criterion B restricted geographic distribution.

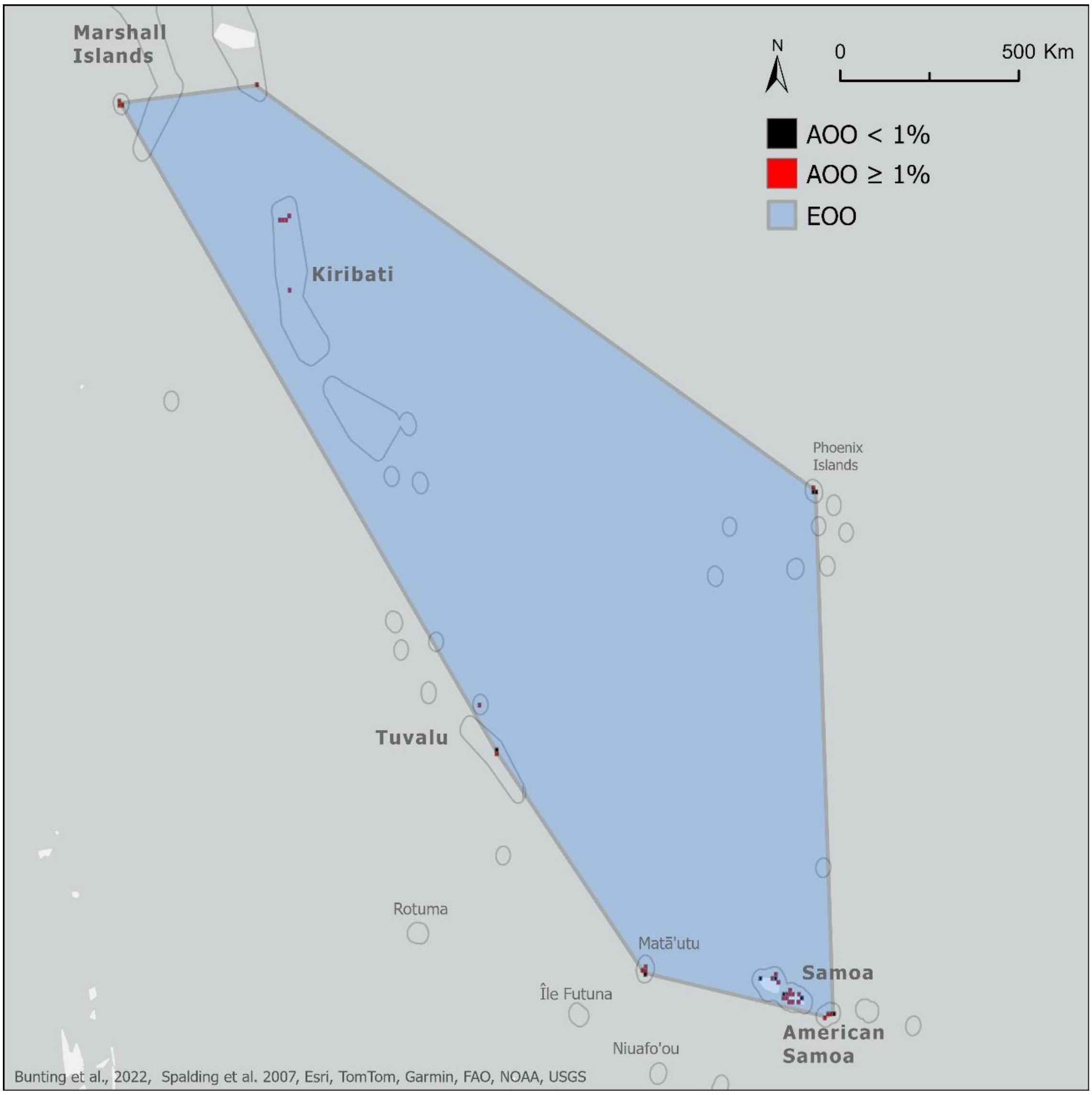


Figure 5. The Central Pacific mangrove Extent Of Occurrence (EOO) and Area Of Occupancy (AOO) in 2020. Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022). The red 10 x 10 km grids (n=31.) are more than 1% covered by the ecosystem, and the black grids <1% (n= 9).

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 little reliable data to evaluate this subcriterion for the entire province, and therefore the Central 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 Central Pacific mangrove ecosystem boundary, using the spatial extent from 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 ~ -50.8% by 2060, which is above 50% but below the 80% risk threshold, though based on little on-ground data. Therefore, considering that no mangrove recruitment can occur in a submerged system (100% relative severity), but that -50.8% of the ecosystem extent will be affected by SLR, the Central Pacific mangrove ecosystem is assessed as **Endangered (EN)** 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 Central Pacific province is classified as **Data Deficient (DD)** for this subcriterion.

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

Criterion D: Disruption of biotic processes or interactions

The global mangrove degradation map developed by Worthington and Spalding (2018) was used to assess the level of biotic degradation in the Central 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 (30 m resolution), on areas intersecting with the 2017 mangrove extent map (GMW v2). Mangrove pixels were classified as degraded if two conditions were met: 1) at least 10 out of 12 degradation indices showed a decrease of more than 40% compared to the previous period; and 2) all 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), 9.6% of the Central Pacific mangrove area is classified as degraded, resulting in an average annual rate of degradation of 0.6%. However, owing to the small scales of many Central Pacific mangroves, higher resolution spatial analyses are needed (Crameri and Ellison 2022). For example, atoll islands commonly have mangrove coasts of <30 m width and the whole island is <50 m width (Crameri and Ellison 2024), so many critical habitat details are not picked up by large scale determinations. Thus, the Central Pacific mangrove province is assessed as **Data Deficient (DD)** 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 Central Pacific ecosystem is classified as **Data Deficient (DD)** 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 50 years period	**A3** Historical (1750)
	DD	**DD**	**DD**
B. Restricted Geo. Distribution	**B1** Extent of Occurrence	**B2** Area of Occupancy	**B3** # Threat-defined Locations < 5?
	LC	**VU**	**DD**
C. Environmental Degradation	**C1** Past 50 years (1970)	**C2** Future or any 50 years period	**C3** Historical (1750)
	DD	**EN**	**DD**
D. Disruption of biotic processes	**D1** Past 50 years (1970)	**D2** Future or any 50 years period	**D3** Historical (1750)
	DD	**DD**	**DD**
E. Quantitative Risk analysis	**NE**		
OVERALL RISK CATEGORY	**EN**		

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

Overall, the status of the Central Pacific mangrove ecosystem is assessed as **Endangered (EN).**

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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
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera gymnorhiza*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora apiculata*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora samoensis*	NT
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora stylosa*	LC
Magnoliopsida	Myrtales	Combretaceae	*Lumnitzera littorea*	LC
Magnoliopsida	Myrtales	Lythraceae	*Sonneratia alba*	LC
Magnoliopsida	Sapindales	Meliaceae	*Xylocarpus granatum*	LC

2. List of Associated Species

List of taxa names 77 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 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
Magnoliopsida	Myrtales	Lythraceae	*Pemphis acidula*	LC	
Polypodiopsida	Polypodiales	Pteridaceae	*Acrostichum speciosum*	LC	(Mangrove fern)
Actinopterygii	Albuliformes	Albulidae	*Albula glossodonta*	VU	Shortjaw bonefish
Actinopterygii	Anguilliformes	Muraenidae	*Gymnothorax monochrous*	LC	
Actinopterygii	Anguilliformes	Ophichthidae	*Scolecenchelys macroptera*	LC	
Actinopterygii	Anguilliformes	Muraenidae	*Uropterygius concolor*	LC	Brown moray eel
Actinopterygii	Atheriniformes	Atherinidae	*Atherinomorus lacunosus*	LC	Hardyhead silverside
Actinopterygii	Aulopiformes	Synodontidae	*Saurida nebulosa*	LC	Clouded lizardfish
Actinopterygii	Clupeiformes	Engraulidae	*Encrasicholina punctifer*	LC	Buccaneer anchovy
Actinopterygii	Clupeiformes	Clupeidae	*Sardinella melanura*	LC	Blacktip sardinella
Actinopterygii	Elopiformes	Elopidae	*Elops hawaiensis*	DD	Giant herring
Actinopterygii	Elopiformes	Megalopidae	*Megalops cyprinoides*	DD	Indo-pacific tarpon
Actinopterygii	Gobiiformes	Gobiidae	*Amblygobius esakiae*	LC	Snout-spot goby
Actinopterygii	Gobiiformes	Gobiidae	*Asterropteryx semipunctata*	LC	Starry goby
Actinopterygii	Gobiiformes	Eleotridae	*Bostrychus sinensis*	LC	Four-eyed sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Butis butis*	LC	Crimson-tipped gudgeon
Actinopterygii	Gobiiformes	Eleotridae	*Eleotris fusca*	LC	Brown spinecheek

Class	Order	Family	Scientific name	RLTS category	Common name
					gudgeon
Actinopterygii	Gobiiformes	Eleotridae	*Eleotris melanosoma*	LC	Broadhead sleeper
Actinopterygii	Gobiiformes	Gobiidae	*Feia nympha*	LC	Nymph goby
Actinopterygii	Gobiiformes	Gobiidae	*Glossogobius circumspectus*	LC	Circumspect goby
Actinopterygii	Gobiiformes	Gobiidae	*Mahidolia mystacina*	LC	Flagfin prawn goby
Actinopterygii	Gobiiformes	Gobiidae	*Mangarinus waterousi*	DD	Uchiwahaze
Actinopterygii	Gobiiformes	Gobiidae	*Oligolepis stomias*	DD	Plain teardrop goby
Actinopterygii	Gobiiformes	Gobiidae	*Oxyurichthys ophthalmonema*	LC	Eyebrow goby
Actinopterygii	Gobiiformes	Gobiidae	*Oxyurichthys takagi*	LC	
Actinopterygii	Gobiiformes	Gobiidae	*Psammogobius biocellatus*	LC	Sleepy goby
Actinopterygii	Mugiliformes	Mugilidae	*Planiliza subviridis*	LC	Greenback mullet
Actinopterygii	Ophidiiformes	Carapidae	*Encheliophis homei*	LC	Silver pearlfish
Actinopterygii	Perciformes	Carangidae	*Atule mate*	LC	Yellowtail scad
Actinopterygii	Perciformes	Pomacentridae	*Dascyllus trimaculatus*	LC	Threespot damselfish
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus coeruleopunctatus*	LC	Whitespotted grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus malabaricus*	LC	(Malabar grouper)
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus miliaris*	LC	Netfin grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus tauvina*	DD	Greasy grouper
Actinopterygii	Perciformes	Apogonidae	*Fowleria variegata*	LC	Variegated cardinalfish
Actinopterygii	Perciformes	Kuhliidae	*Kuhlia salelea*	DD	Salele flagtail
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus harak*	LC	Thumbprint emperor
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus nebulosus*	LC	Spangled emperor
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus semicinctus*	LC	Black-spot emperor
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulviflamma*	LC	Dory snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulvus*	LC	Blacktail snapper
Actinopterygii	Perciformes	Mullidae	*Parupeneus barberinus*	LC	Dash-and-dot goatfish
Actinopterygii	Perciformes	Ephippidae	*Platax orbicularis*	LC	Orbiculate batfish
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus gibbosus*	LC	Brown sweetlips
Actinopterygii	Perciformes	Haemulidae	*Pomadasys kaakan*	LC	Javelin grunter
Actinopterygii	Perciformes	Nemipteridae	*Scolopsis ciliata*	LC	Saw-jawed monocle bream
Actinopterygii	Perciformes	Siganidae	*Siganus lineatus*	LC	Lined rabbitfish
Actinopterygii	Perciformes	Siganidae	*Siganus vermiculatus*	LC	Vermiculated spinefoot
Actinopterygii	Perciformes	Apogonidae	*Sphaeramia orbicularis*	LC	Orbiculate cardinalfish
Actinopterygii	Pleuronectiformes	Soleidae	*Brachirus aspilos*	LC	Dusky sole
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Pseudorhombus arsius*	LC	Largetooth flounder
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron manilensis*	LC	Narrow-lined puffer
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron reticularis*	LC	Reticulated pufferfish
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron stellatus*	LC	Stellate puffer
Aves	Charadriiformes	Charadriidae	*Charadrius mongolus*	LC	Lesser sandplover

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Columbiformes	Columbidae	*Ducula oceanica*	VU	Micronesian imperial-pigeon
Aves	Columbiformes	Columbidae	*Ptilinopus fasciatus*	LC	Samoan fruit-dove
Aves	Columbiformes	Columbidae	*Ptilinopus porphyraceus*	LC	Tongan fruit-dove
Aves	Coraciiformes	Alcedinidae	*Todiramphus chloris*	LC	Collared kingfisher
Aves	Coraciiformes	Alcedinidae	*Todiramphus recurvirostris*	LC	Flat-billed kingfisher
Aves	Passeriformes	Meliphagidae	*Foulehaio carunculatus*	LC	Polynesian wattled honeyeater
Aves	Passeriformes	Monarchidae	*Myiagra albiventris*	NT	Samoan flycatcher
Aves	Passeriformes	Meliphagidae	*Myzomela cardinalis*	LC	Cardinal myzomela
Aves	Pelecaniformes	Ardeidae	*Egretta sacra*	LC	Pacific reef-egret
Aves	Suliformes	Fregatidae	*Fregata ariel*	LC	Lesser frigatebird
Aves	Suliformes	Fregatidae	*Fregata minor*	LC	Great frigatebird
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus melanopterus*	VU	Blacktip reef shark
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Negaprion acutidens*	EN	Sharptooth lemon shark
Gastropoda	Cycloneritida	Neritidae	*Neritodryas subsulcata*	DD	Weakly cut nerite
Gastropoda	Ellobiida	Ellobiidae	*Cassidula crassiuscula*	LC	
Gastropoda	Ellobiida	Ellobiidae	*Laemodonta bella*	LC	
Gastropoda	Ellobiida	Ellobiidae	*Melampus striatus*	LC	
Gastropoda	Neogastropoda	Conidae	*Conus frigidus*	LC	Frigid cone
Gastropoda	Neogastropoda	Conidae	*Conus varius*	LC	Freckled cone
Gastropoda	Stylommatophora	Achatinellidae	*Lamellidea oblonga*	LC	
Gastropoda	Stylommatophora	Achatinellidae	*Lamellidea pusilla*	LC	
Reptilia	Squamata	Boidae	*Candoia bibroni*	LC	Pacific boa