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Mangroves of the Tropical East Pacific

VU

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Abstract

Mangroves of the Tropical East Pacific (TEP) province is a regional ecosystem subgroup (Level 4 unit of the IUCN Global Ecosystem Typology), present in the coastal ecoregions of the Mexican Tropical Pacific, Chiapas-Nicaragua, Nicoya, Panama Bight, and Guayaquil. In 2020, mangroves cover 7782 km^2 in the province, representing 5.3% of the global coverage.

In the province, there are eight true mangrove species; however, regional experts recognize other related plants classified as associated plants. The IUCN Red List includes 224 species (217 Animalia and seven Plantae species), supported by records in the Global Biodiversity Information Facility GBIF.

It is estimated that the mangroves of the TEP showed a net change of -1.9% from 1996 to 2020; under this trend, a decrease of 3.3% is projected in 50 years, which is below 30%, classifying criterion A2 as least concern. However, based on indicative figures, a decrease of around 40% was estimated in the last 50 years (1970-2020); which as this exceeds 30%, the mangroves are vulnerable under Criterion A1. Although threats such as deforestation, human activities, pollution, infrastructure development, modification of natural systems, and invasion of exotic species are reported, none promote total disappearance; therefore, criteria B3 is classified as least concern. In a sea-level rise scenario (IPCC RCP8.5), ≈ 9.8% of the TEP mangroves would be submerged by 2060, which is below the 30% risk threshold for criterion C2. Furthermore, 1.5% of the province's mangrove is suffering degradation, with the potential to increase to 4.5% over 50-year period; this ranks the mangroves as least concern under criterion D2b.

Overall, **the Tropical East Pacific mangrove ecosystem was assessed as Vulnerable (VU)** with the available information. It is considered that there is insufficient data to assess the other criteria, therefore, it is recommended to update the data to increase the precision of the evaluation and enable the quantitative analysis of risks.

Citation:
Montes-Chaura, C., Rangel-Ch, J. O., Caicedo-García, JP., Pardo-Spiess, S., Chasqui, L., Cortés-C, D., E. Fraiz-Toma. A., Aponte, H., Calle, P., Quesada-Román, A., Blanco-Libreros, J. F., Lozano-Arias, L., Romero-D'Achiardi, D., Carolina-Hoyos, T., Troche-Souza, C., Molina-Moreira, N., Tovilla-Hernández, C., Felipe Lazarus, J., Sierra-Correa, P. C., Di Nitto, D., Calles Procel, A., Suárez. E. L. (2024). '*IUCN Red List of Ecosystems. Mangroves of the Tropical East Pacific'*. EcoEvoRxiv.

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

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

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

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

Mangroves of The Tropical East Pacific

VU

1. Ecosystem Classification

IUCN Global Ecosystem Typology (version 2.1. Keith *et al.*, 2020):

Transitional Marine-Freshwater-Terrestrial realm

- MFT1 Brackish tidal biome
  - MFT1.2 Intertidal forests and shrublands
    - **MFT1.2_4_MP_43x** Mangroves of the Tropical East 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]
- 12 Marine Intertidal
  - 12.7 Mangrove Submerged Roots

2. Ecosystem Description

Spatial distribution

The Mangroves in the Tropical East Pacific province include intertidal forests and shrublands of the Mexican Tropical Pacific, Chiapas-Nicaragua, Nicoya, Panama Bight, and Guayaquil ecoregions (Spalding *et al.*, 2007). Therefore, mangrove cover in this province span the coastlines of Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, and northern Peru (Figure 1).

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[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.

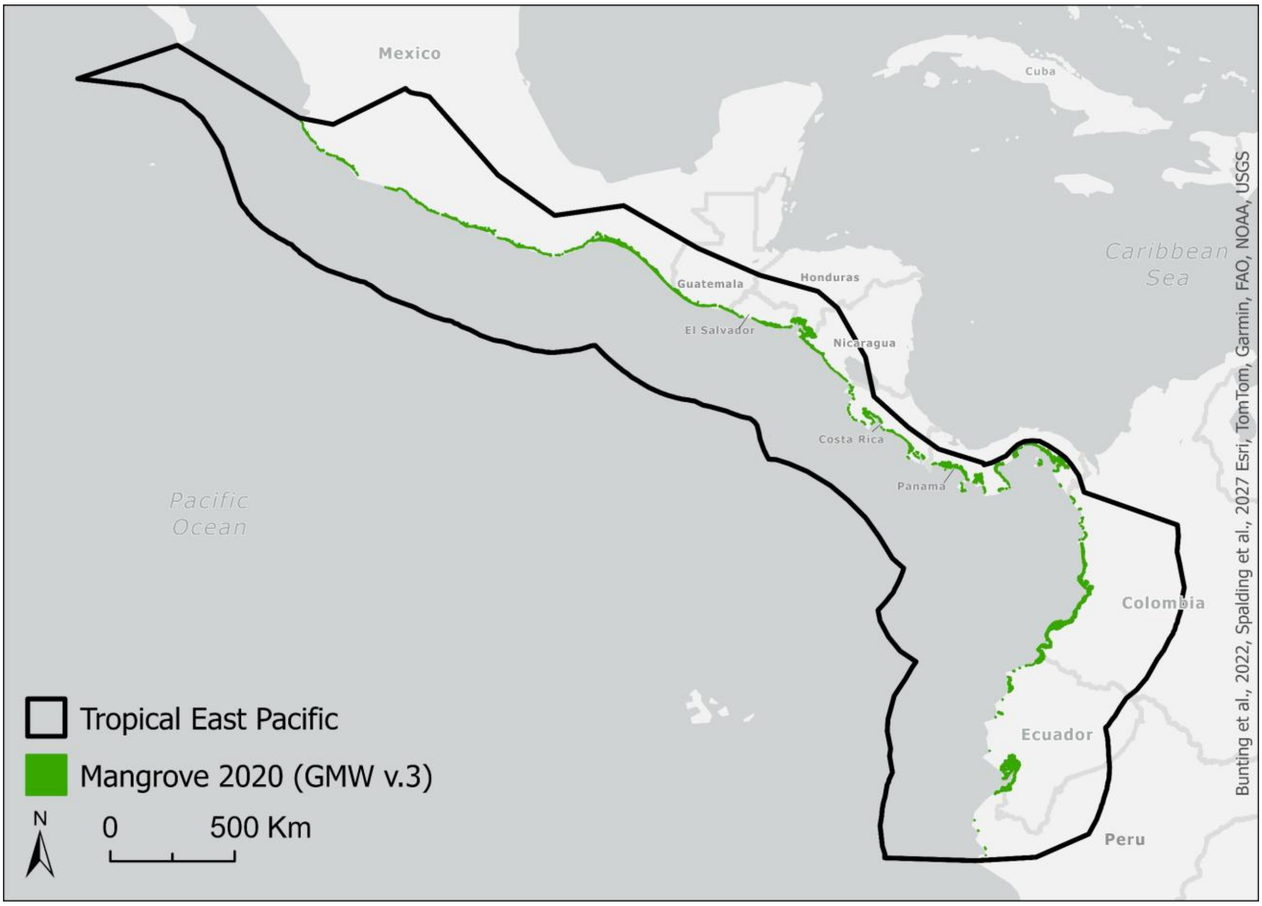


Figure 1. The mangroves of the Tropical East Pacific province.

The estimated extent of mangroves in this province in 2020 was 7782 km^2 representing about 5.3% of the global mangrove area. There has been a -1.9 % net area change since 1996 (Bunting *et al*., 2022).

Table 1 presents the mangrove area in the territories or countries of the Tropical East Pacific province.

Table 1. Estimated extent of mangroves in the Tropical East Pacific province in 2020 (Bunting *et al*., 2022)

Territory or country	**Area (km^2)**
Colombia	1972.0
Ecuador	1485.6
Panama	1462.2
Mexico	1075.7
Nicaragua	386.2
Costa Rica	371.0
El Salvador	370.8
Honduras	362.5
Guatemala	241.1
Peru	54.9
Total	**7782**

Biotic components of the ecosystem (characteristic native biota)

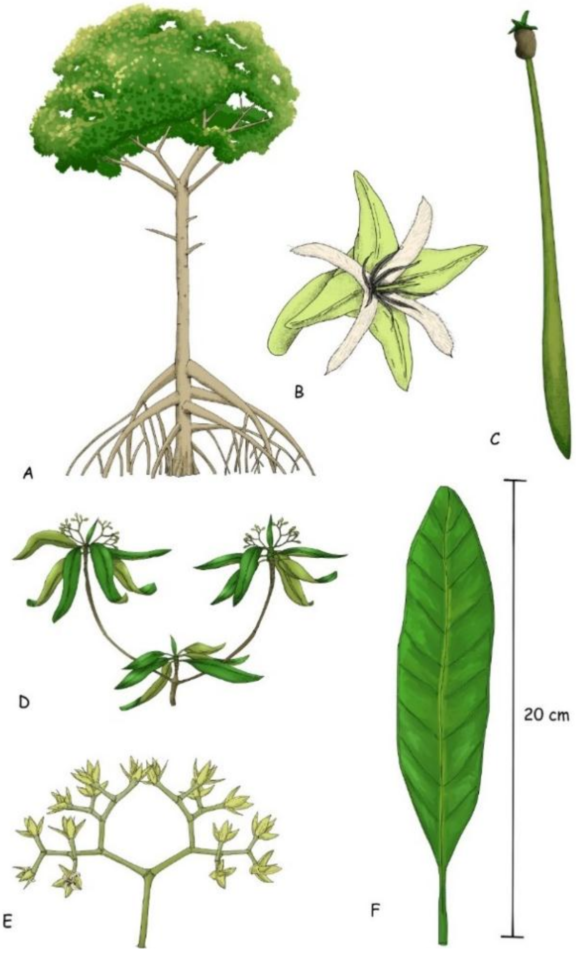
For the mangroves of the Tropical East Pacific, eight species of true mangroves have been recorded. 1) *Avicennia bicolor* Standl. 1923, Vulnerable (VU), recorded from Mexico to Panama; 2) *Avicennia germinans* L. 1764 (Black mangrove), Least concern (LC), from Mexico to Peru; 3) *Laguncularia racemosa* (L.) C.F. Gaertn. 1807 (White mangrove), (LC), from Mexico to Peru; 4) *Pelliciera rhizophorae* Planch. and Triana. 1862 (Tea mangrove), (VU), from Nicaragua to Ecuador; 5) *Rhizophora racemosa* G. Mey. 1818, (LC), from El Salvador to Peru; and 6) *Rhizophora samoensis* (Hochr.) Salvoza. 1936, Near threatened (NT), Mexico-Honduras-Panama-Ecuador (IUCN, 2022). In addition, 7) *Rhizophora mangle* L. 1753 (Red Mangrove), (LC), from Mexico to Peru (Brako and Zarucchi, 1993); and 8) *Pelliciera benthami* (Planch and Triana) Cornejo. 2020, Not Evaluated (NE); Panama (Cornejo and Bonifaz, 2020; Duke, 2020) have been reported in the province.

Avicennia germinans flowers in La Boncana mangrove, Peru (photo credit: Héctor Aponte).

Three of the 10 countries with the tallest mangrove canopies in the world are in the Tropical East Pacific province: Colombia, Costa Rica, and Panama. Their mangroves are located mainly in remote estuarine regions with over 500 cm of rainfall per year and average temperatures of 25.6 °C; and where the coastal areas have a low human population density, potentially high nutrient availability, low soil salinity, and significant protection against high-energy winds and waves from cyclones (Simard *et al*., 2019).

Rhizophora mangrove. in Bocagrande, San Andrés de Tumaco, Colombia (photo credit: Laura Lozano Arias).

Regional mangrove experts recognize some plant species directly related to the mangrove ecosystem, but which are not unanimously classified as true mangroves, such as *Rhizophora x harrisoni* Leechm, *Mora oleifera* (Triana ex Hemsl.) Ducke, *Conocarpus erectus* L, *Tabebuia palustris* Hemsl, *Annona glabra* L, *Hibiscus tiliaceus* (L.) Fryxell, and *Pterocarpus officinalis* Jacq (Cornejo *et al*., 2012; ANAM-ARAP, 2013; Villaseñor, 2016; Prance, 2018; Condit, Aguilar and Pérez, 2020). And there are many other mangrove associates, including trees/shrubs, linas/vines, herbs, epiphytes, parasites, stranglers, and ferns such as *Acrostichum danaeifolium* Langsd. and Fisch, *Acrostichum aureum* L, *Pavonia rhizophorae* Killip ex Kearney, *Crenea patentinervis* (Koehne) Standl, and *Sobralia rhizophorae* Cornejo and Dodson (Alvarado and Trusty, 2004; Duke, 2006; Cornejo, 2014).



Rhizophora harrisonii: A) roots, trunk, and canopy; B) flower; C) propagule; D) arrangement of branches and inflorescence; E) detail of the inflorescence; F) lanceolate leaf (Illustrator: Mauricio Macías).

There are at least 224 species (217 Animalia and seven Plantae), including fishes (Actinopterygii and Chondrichthyes), snails (Gastropoda), reptiles (Reptilia) and birds (Aves) associated with mangrove habitats in the IUCN Red List of Threatened Species (RLTS; IUCN, 2022) that have records of natural history collection specimens or observations records in the GBIF within this province (GBIF, 2022). Of these species, nine are categorized as Vulnerable (VU), four species are Endangered (EN), and three are Critically Endangered (CR). Among them are some birds like the *Amazona auropalliata* Lesson, 1842 (Yellow-naped Parrot), (CR); *Amazona lilacina* Lesson, 1844 (Ecuadorian Red-fronted amazon), (CR); the *Amazilia boucardi* Mulsant, 1877 (Mangrove hummingbird), (EN); and large fishes like the *Pristis pristis* Linnaeus, 1758 (Largetooth sawfish), (CR); and the *Ginglymostoma unami* Del Moral-Flores, Ramíz-Antonio, Angulo and Pérez-Ponce de León, 2015 (Pacific Nurse shark), (EN) which are threatened by human activities like fishing and habitat loss (Urquizo *et al*., 2011; Albuja *et al*., 2012).

Some regional experts have documented species not listed in the RLTS (Appendix 2 - Table 4) filtered for the province. For example, the *Ara ambiguus guayaquilensis* (Guayaquil parrot), (CR) and the *Platalea ajaja* (Roseate spoonbill) (Urquizo *et al*., 2011; Albuja *et al*., 2012) occur in mangrove areas of the Gulf of Guayaquil; also *Psittacara erythrogenys* (Red-masked Parakeet) and *Tursiops truncatus* (Bottlenose dolphins). However, these may constitute species that interact directly or indirectly with the mangrove ecosystem.

Red-masked Parakeet (Psittacara erythrogenys, left) and Roseate Spoonbill (Platalea ajaja, right) in the Área Nacional de Recreación Isla Santay e Isla Gallo, Ecuador (photo credit: Cristhian Geovanny).

Bottlenose dolphins (Tursiops truncatus) in Manglares El Morro Wildlife Refuge, Posorja, Ecuador (photo credit: Paola Calle).

Abiotic Components of the Ecosystem

Abiotic factors that can influence the mangrove ecosystem include storm-driven processes, rainfall, tidal influence, freshwater input, climatic factors such as temperature, sedimentation rate, light, nutrient availability, and salinity (Krauss *et al*., 2008; McGowan, 2010; Pérez *et al*., 2020; Ellison, 2021). Mangrove distribution is also influenced by interactions among landscape position, subsidence, and disturbance by pests and predators. Rainfall and sediment supply from rivers and currents promote mangrove establishment and persistence, while waves and large tidal currents destabilize and erode mangrove substrata, mediating local-scale dynamics in ecosystem distributions. High rainfall reduces salinity stress and increases nutrient loading from adjacent catchments, while tidal flushing also regulates salinity.

The climate of the Eastern Tropical Pacific, in which the Tropical East Pacific is included as an ecoregion (Spalding *et al*., 2007), is markedly asymmetric around the equator, with warmer sea surface temperatures and higher rainfall in the northern Pacific (Szoeke and Xie, 2008). A geospatial analysis based on the NASA POWER project database shows that climate variables between 1981 and 2022 at 40 selected sites within the province (see Appendix 3- Table 5) had an average value of 1709.3 ± 1245.8 mm mean annual precipitation (with a minimum annual average of 112.9 mm in Peru and a maximum annual average of 5847.5 mm in Colombia), 26.0 ± 1.5 °C mean annual temperature (22.4 Mexico - 28.9 Nicaragua) and a mean annual relative humidity of 77.8 ± 7 % (63.7% Honduras - 89.9% Colombia).

For example, a specific case is the Colombian Biogeographic Chocó, where coastal areas or estuarine environments between 0 and 4 m in elevation have a bimodal-tetraseasonal precipitation distribution regime with an annual amount of 3088 mm. The maximum temperature is 33.7 °C, the average is 27.2 °C and the minimum is 19.5 °C (Rangel and Arellano, 2004). The substrata in the swampy areas contain a lot of mud, towards inland of the continent the sand and clay increases (Cortés, 1993). The soils of the alluvial plain contain easily alterable minerals, feldspars and ferromagnesian minerals in the sand fraction and amorphous materials in the clay fraction, with good cation exchange capacity, high base saturation values and low exchange aluminum content; in general, they have clay loam and clay textures (Castiblanco, 1990). Elements such as these are factors that can influence the establishment of soil biogeochemical conditions (Chen and Ye, 2010; Gutiérrez *et al*., 2016). Also, the conditions of the sediment type are variables that affect the formation of mangroves (Acuña-Piedra and Quesada-Román, 2017; Guzmán-Sánchez *et al*., 2023).

Key processes and interactions

The cause-effect model of the mangrove ecosystem of the Tropical East Pacific province is shown in Figure 2. It shows the threats, the characteristic biota, and the biotic and abiotic processes that develop there. Mangroves act as fundamental species that provide habitat to many others and drive ecosystem processes (Ellison *et al*., 2005). They serve as habitat for a variety of fauna, including migratory bird species, fishes, marine invertebrates, and amphibians. These animals use mangroves in many ways, *e.g.* for feeding, breeding, spawning, roosting, as shelter from predators, or as a temporary refuge for migratory species (Kathiresan and Bingham, 2001; Nagelkerken *et al*., 2008). However, changes generated by the threats to the mangrove ecosystem could have negative consequences for their survival and reproduction (Ward *et al*., 2016; Villalba, 2006). Mangroves possess traits such as pneumatophores, salt excretion glands, vivipary and propagule buoyancy that promote survival and recruitment in poorly aerated, saline, mobile, and tidally inundated substrata. They exhibit high efficiency in nitrogen use and nutrient resorption. Mangroves produce large amounts of detritus (*e.g.* leaves, twigs, and bark), which is either buried in waterlogged sediments, consumed by crabs and gastropods, the decomposed further by meiofauna, fungi and bacteria, thus mobilizing carbon and nutrients to other trophic levels in the mangrove and coastal food web.

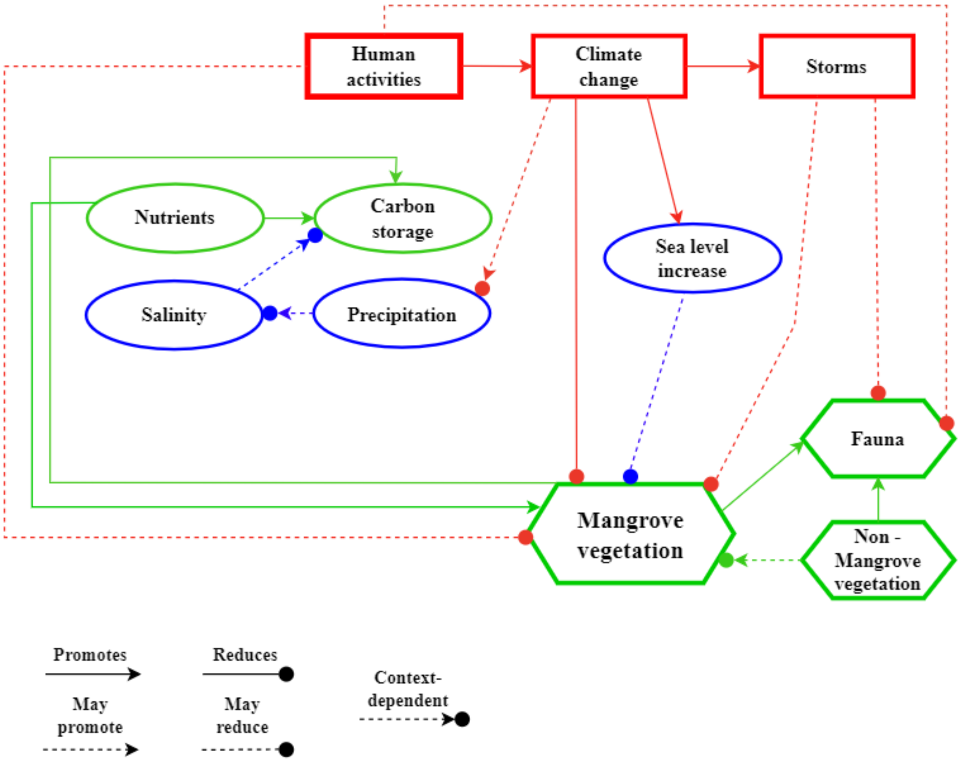


Figure 2. Conceptual model of some key mangrove ecosystem processes: threats (red rectangles), characteristic biota (green hexagons), biotic processes (green ovals), and abiotic processes (blue ovals).

Mangrove ecosystems also serve as major blue carbon sinks, incorporating organic matter into sediments and living biomass. Based on the research of Simard *et al.* (2019), which presents a global analysis of mangrove aboveground biomass, data were segmented according to extent of occurrence (EOO) and combined into a provincial mosaic. The mean and standard deviation of the ploted histogram for aboveground biomass resulted in 115.98 ± 98.47 t/ha for the Tropical East Pacific province.

Climate change is increasing the frequency and intensity of tropical cyclones, which can cause even more severe damage to mangroves (Sugi *et al*., 2009; Bender *et al*., 2010; Lavender and Walsh, 2011; Walsh *et al.*, 2012). Climate change also affects other ecological processes such as sea-level rise, caused by thermal expansion of the oceans and melting glaciers, resulting in erosion and the loss of mangrove habitat (Saintilan *et al*., 2020; Walsh *et al*., 2012). Also, climate change is expected to affect precipitation, which may influence the growth, distribution, and potential extent of mangroves (Gilman *et al*., 2008).

Interactions between biotic and abiotic factors are fundamental to mangrove structure and function. These parameters can influence mangrove species composition and their ability to store carbon (Flores-Verdugo *et al*., 2007; Sanders *et al*., 2010). Interactions between climatic factors, hydrology, and plant biodiversity are key to understanding mangrove dynamics and their role in the global carbon cycle (Rahman, 2021).

Moderate rainfalls play a crucial role in the nutrient cycling of mangroves; an increase in rainfall can have a significant impact on mangrove growth and productivity, reducing salinity stress and increasing nutrient loading (Adame, 2011; Alongi, 2018). Different nutrient concentrations can also affect the distribution of species and their competitive ability (Chen and Twilley, 1998; Reef *et al*., 2010), as well as providing better breeding and nursery grounds for birds, reptiles, and mammals in this environment (Duncan *et al*., 2016). Future changes in nutrient supply will be closely related to precipitation intensity (Terada, 2017); however, the exact magnitude of this impact will depend on several area-specific geomorphological and climatic factors (Waycott *et al*., 2011).

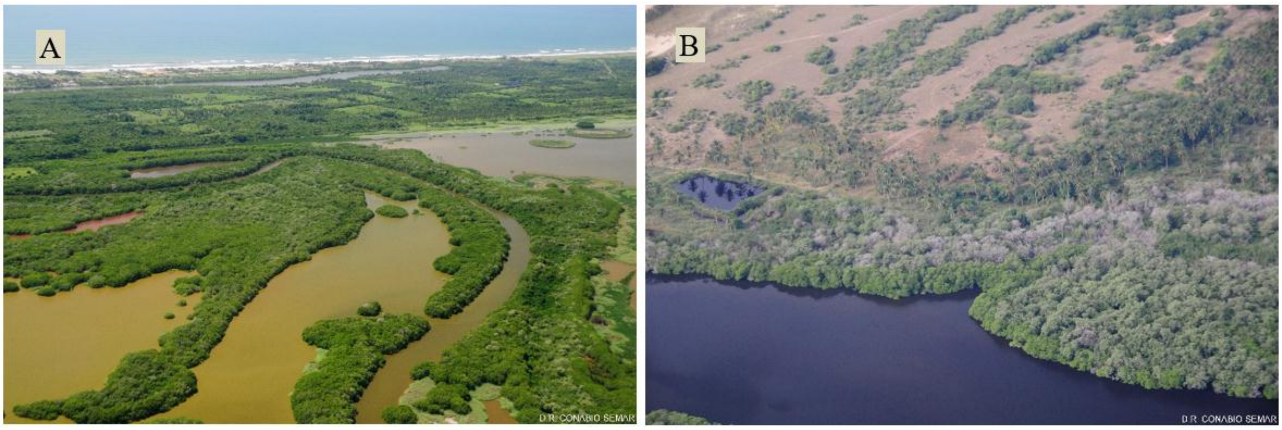
3. Ecosystem Threats and vulnerabilities

Main threatening process and pathways to degradation

Mangrove deforestation arises from various factors, including agriculture and aquaculture, urbanization, associated coastal development like port infrastructure, overharvesting, and pollution stemming from domestic, industrial, and agricultural land use. The location of mangrove forests within intertidal areas renders them vulnerable to predicted sea-level rise because of climate change. Tropical storms and tsunamis can damage mangrove forests through direct defoliation and destruction of trees, as well as through the mass mortality of animal communities within the ecosystems.

Escobar *et al*., (2020) reported destructive tsunamis on the Pacific coast of Colombia in 1906 and 1979, and assessed tsunami risk in populated areas of this coast using deterministic models that consider seafloor deformation. The results indicate maximum tsunami wave heights of up to 4.66 meters in places such as Tumaco, so that the mangroves present there might have suffered degradation.

Shrimp farms inside the mangrove ecosystem within El Salado Fauna Production Reserve, Guayaquil, Ecuador (photo credit: Paola Calle).



Tectonic plains with mangroves along the coastline, which decreases with the advance of crops in Acapulco de Juarez. Guerrero, Mexico (A) and Tecpan de Galeana, Guerrero, Mexico (B) (photo credits: Samuel Velazquez. (2015) (A) and Carlos Troche (2015) (B)).

According to Tavera *et al*., (2021), in the Cuerval sector of the Cauca Department, in the Colombian Pacific, mangroves are primarily affected by the hunting of the *Phalacrocorax olivaceus* (Olivaceous cormorant) chicks. The method of hunting can be summarized as cutting down mangrove trees to reach the nests where the fledglings are located.

Mangrove degradation due to human activities in Cuerval sector, Cauca, Colombia (Photo credit: Diana Romero D'Achiardi).

Human activities have had a strong impact on mangrove vegetation, generating changes in the cover due to land conversion processes for the development of economic activities such as agriculture, aquaculture, or human development (Giri *et al*., 2008; Malik *et al*., 2017; Tuholske *et al*., 2017; Friess *et al*., 2021).

A recent study that included Peruvian mangroves shows littering as the most frequent cause of change. Other frequent causes of change are impacts from tourism and pollution from the fishing and aquaculture industries (Gomez *et al*., 2023). Other reports from mangrove ecosystems in Ecuador show how urban expansion and industrial growth have affected sediment and water quality conditions, including reduced dissolved oxygen concentrations, greater salinity fluctuations, and increased ammonia concentrations in the sediment (Calle *et al*., 2018). Additionally, marine litter in addition to affecting the health of the mangrove ecosystem also affects the well-being of Ecuadorian communities that inhabit and depend on this ecosystem (McMullen *et al*., 2023).

Litter is one of the most frequent causes of change in mangroves, La Bocana, Peru
(Photo credit: Héctor Aponte).

In Buenaventura, Colombia, mangrove forests near the city were found to be among the most polluted coastal areas in the world, with trash densities varying widely. Surface litter serves as temporary habitat for a variety of marine organisms, which migrate from other coastal areas. This raises concerns about the potential transfer of contaminants, such as plastics or chemicals, through food webs (Riascos *et al*., 2019). Also, in Buenaventura Bay, located in the central area, port infrastructure is a significant threat. Shrimp aquaculture developments that began around 1984 in Tumaco, Colombia (Muñoz, 2019) have left abandoned infrastructure, which can alter key ecosystem processes.

In Ecuador since the 1970s, coastal mangrove forests were cut down for the construction of shrimp ponds to supply the international market demand for farmed shrimp (Hamilton, 2020). The rapid growth of shrimp aquaculture and indiscriminate deforestation of mangroves has given rise to a series of socio-ecological conflicts with little input from fishing communities that depended on mangrove resources to ensure their livelihoods and subsistence (Beitl *et al.*, 2022). In addition, according to Pernia *et al.*, (2019), pollution in mangroves poses a serious threat due to high levels of toxic heavy metals like cadmium, mercury, and lead. These pollutants harm the survival, growth, and reproduction of organisms and can accumulate in species like red crabs and shellfish, posing risks to human health. Additionally, mangroves suffer from hydrocarbon contamination originating from various sources such as untreated sewage, industrial waste, oil spills, and boat engine runoff (Pernia *et al.*, 2019). As well seen, particularly in Tumaco, Colombia, activities such as illegal mining, illegal coca cultivation, expansion of oil palm plantations, intensive agricultural practices, and indiscriminate logging (Lopez-Soler, 2021), have resulted in the deterioration of conservation areas, such as mangroves, due to occupation processes, high levels of contamination, and the absence of clear guidelines, regulations, and urban development executions (Córdoba, 2017; Lopez-Soler, 2021).

Besides, regarding modifications to natural systems, examples are found such as the diversion of water in the Patía River delta in Colombia, begun in 1972. This change has altered hydrology and sedimentation, resulting in accumulations of sediments, changes in water salinity and loss of mangrove areas. In addition, an invasion of freshwater vegetation and recurrent defoliation due to pests is observed. Mangrove erosion, caused by factors such as tectonic subsidence and lack of sediment, is evident on barrier islands. These changes endanger the survival of mangroves in the Sanquianga Mangrove National Reserve (Restrepo and Cantera, 2013).

Like Mexico, between 1970 and 2005, the main anthropogenic activities with an impact on mangrove areas in the Central and South Pacific were the establishment of aquaculture farms and tourist areas (Velázquez-Salazar *et al*., 2021). For the period from 2005 to 2010, the notable developments were hydraulic infrastructure and construction zones (Velázquez-Salazar, *et al*., 2019). In the Central Pacific (extreme north of the province), the growth of tourist cities such as Puerto Vallarta, Barra de Navidad and Manzanillo stands out, while further south, the development and port expansions of Lázaro Cárdenas in Michoacán and Acapulco in Guerrero have also contributed to the loss of mangrove cover.

Invasive species, for example *Eichhornia crassipes*, which can occur in the mangrove ecosystem, could have the potential to negatively affect mangrove vegetation (Biswas *et al.*, 2018; Chacón-Madrigal *et al.*, 2022). This plant has the ability to rapidly increase its biomass and form dense clumps, spreading by vegetative stolons and extending to completely cover water bodies such as lakes and wetlands (Stohlgren *et al.*, 2013). This process leads to the displacement of native aquatic species and a decrease in oxygen levels available to fish. In addition, this species hinders the movement of propagules, effectively competes for nutrients present in the water, and negatively affects the regenerative capacity of mangroves (Biswas *et al.*, 2007).

Advance of coastal tourism-urban development in mangrove areas, Puerto Vallarta, Jalisco, Mexico. (photo credit: CONABIO-SEMAR/S. Velazquez (2015)).

Definition of the collapsed state of the ecosystem

Mangroves possess specialized traits that facilitate high nitrogen use efficiency and nutrient resorption, influencing critical processes and functions within their ecosystem (Reef *et al*., 2010; Ellison, 2021). Ecosystem collapse is recognized when the tree cover of diagnostic true mangrove species dwindles to zero, indicating complete loss (100% mortality).

These ecosystems exhibit remarkable dynamism, with species distributions adapting to local shifts in sediment distribution, tidal patterns, and variations in local inundation and salinity gradients. Disruptive processes can trigger shifts in this dynamism, potentially leading to ecosystem collapse, which may manifest through the following mechanisms: a) restricted recruitment and survival of diagnostic true mangroves due to adverse climatic conditions (*e.g*. low temperatures); b) alterations in rainfall, river inputs, waves, and tidal currents that destabilize and erode soft substrata, hindering recruitment and growth; c) shifts in rainfall patterns and tidal flushing altering salinity and nutrient dynamics, thereby impacting overall survival.

In October 2023, as an example of the risks from the intensification of hurricanes due to climate change, in October 2023 category 5 Hurricane Otis, upon making landfall near the Mexican city of Acapulco, devastated mangrove areas in the Tres Palos Lagoon. Using the normalized difference vegetation index (NDVI) as an indicator, 40% of the areas showed a decrease of up to 3.9 standard deviations from the mean value or January-April, 2024. Although there are few studies, some documented cases in the region (*e.g.* Hurricane Carlota, 2012 in Oaxaca), have pointed out that, if hydrological flow conditions are restored, mangroves can recover to similar conditions in a minimum period of eight years (Velázquez, *et al*., 2021), with the species *Laguncularia racemosa* being more resilient compared to *Rhizophora* mangroves, which due to their riparian location tend to be more damaged by these events. If, as some studies indicate, the frequency and intensity of these phenomena increases in the Pacific basin, the risk of complete loss of mangrove areas will also increase.

The increase in temperature, both at the surface and in the lower layers of the sea, as well as the reduction in atmospheric circulation during the summer in tropical areas, has caused an increase in the number of hurricanes of major magnitude (Taillie *et al*., 2020; Herrera-Silveira *et al*., 2022). This increase in the frequency of high-intensity hurricanes poses an even greater threat to mangroves, causing higher rates of coastal erosion, more severe flooding, and more powerful storm surges, with a broader inland impact (Woodruff *et al*., 2013; Herrera-Silveira *et al*., 2022). This may mean that the risk of complete loss of mangroves in some areas will also increase.

Threat Classification

IUCN Threat Classification (version 3.3. IUCN-CMP, 2022) relevant to mangroves of the Tropical East 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
    - 2.1.3 Agro-industry farming
- 2.2 Wood & pulp plantations
    - 2.2.1 Small-holder plantations
    - 2.2.2 Agro-industry plantations
- 2.3 Livestock farming & ranching
    - 2.3.2 Small-holder grazing, ranching or farming
    - 2.3.3 Agro-industry grazing, ranching or farming
- 2.4 Marine & freshwater aquaculture
    - 2.4.1 Subsistence/artisanal aquaculture
    - 2.4.2 Industrial aquaculture

3. Energy production & mining
- 3.1 Oil & gas drilling
- 3.2 Mining & quarrying

4. Transportation & service corridors
- 4.1 Roads & railroads
- 4.2 Utility & service lines
- 4.3 Shipping lanes
- 4.4 Flight paths

5. Biological resource use
- 5.1 Hunting & collecting terrestrial animals
    - 5.1.4 Motivation Unknown/Unrecorded
- 5.2 Gathering terrestrial plants

    - 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]
- 5.4 Fishing & harvesting aquatic resources
    - 5.4.1 Intentional use: subsistence/small scale (species being assessed is the target) [harvest]
    - 5.4.6 Motivation Unknown/Unrecorded

6. Human intrusions & disturbance

- 6.1 Recreational activities
- 6.2 War, civil unrest & military exercises
- 6.3 Work & other activities

7. Natural system modifications

- 7.1 Fire & fire suppression
    - 7.1.1 Increase in fire frequency/intensity
    - 7.1.2 Suppression in fire frequency/intensity
    - 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)
    - 7.2.5 Abstraction of ground water (domestic use)
    - 7.2.6 Abstraction of ground water (commercial use)
    - 7.2.7 Abstraction of ground water (agricultural use)
    - 7.2.9 Small dams
    - 7.2.10 Large dams
- 7.3 Other ecosystem modifications

8. Invasive & other problematic species genes & diseases

- 8.1 Invasive non-native/alien species/diseases
    - 8.1.2 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
    - 9.2.2 Seepage from mining
    - 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
- 9.5 Air-borne pollutants
    - 9.5.1 Acid rain
    - 9.5.2 Smog

        - 9.5.3 Ozone
    - 9.6 Excess energy
        - 9.6.1 Light pollution
        - 9.6.2 Thermal pollution
        - 9.6.3 Noise pollution

10. Geological events

- 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

12. Other options

- 12.1 Ports infrastructure

4. Ecosystem Assessment

Criterion A: Reduction in Geographic Distribution

Subcriterion A1 measures the trend in ecosystem extent during the last 50-year time window. Unfortunately, there is currently no common regional dataset that provides information for the entire target area in 1970. However, country-level estimates of mangrove extent can be used to extrapolate the trend between 1970 and 2020. Accordingly, we compiled reliable published sources (see Appendix 4- Table 6) that contain information on mangrove area estimates close to 1970 (both before and after) for each country within the province. These estimates were then used to interpolate the mangrove area in 1970 in each country. By summing up these estimates, we calculated the total mangrove area in the province. We only considered the percentage of each country's total mangrove area located within the province and the estimated values for 1970 should be considered only indicative (see Appendix 4 for further details of the methods and limitations).

In contrast, to estimate the Tropical East 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).

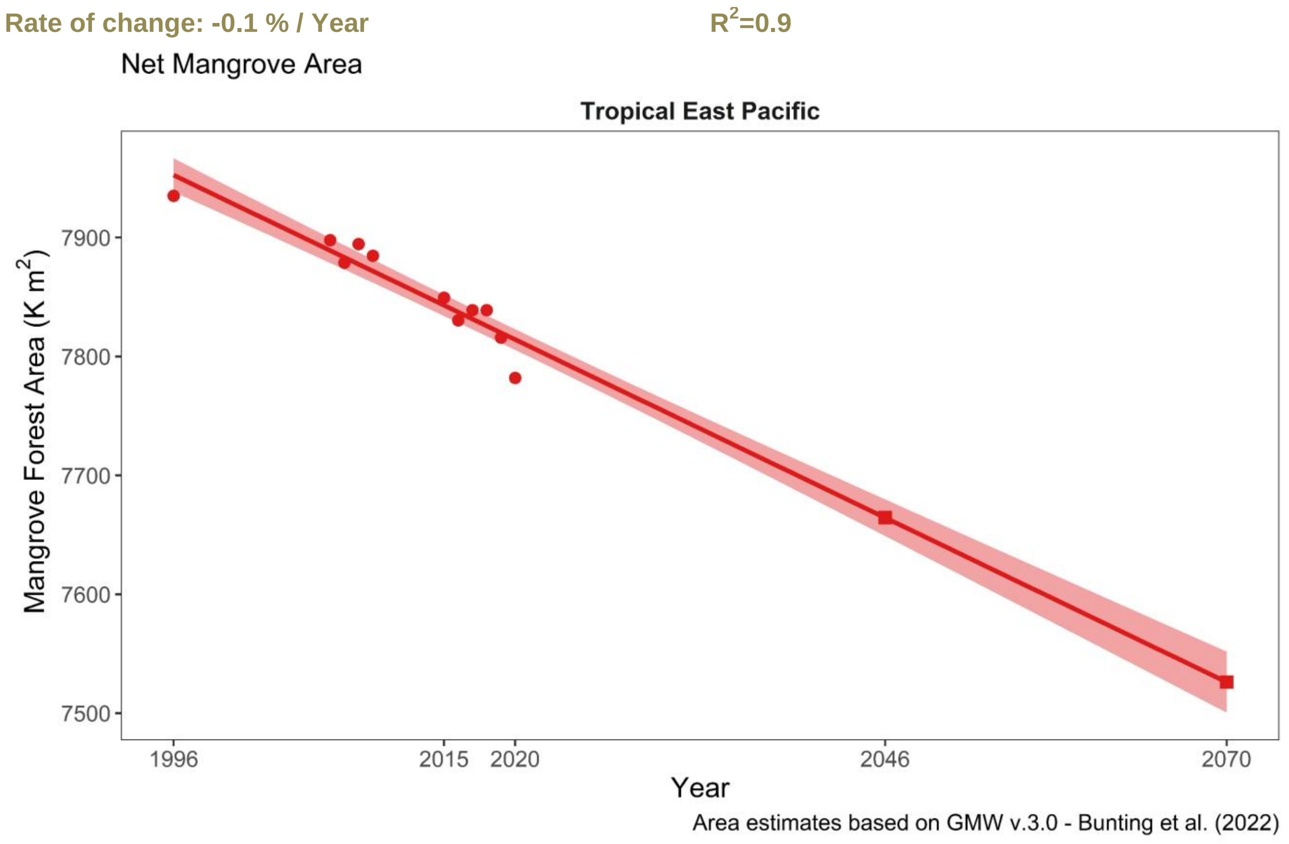
The results of the analysis of subcriterion A1 (Appendix 4 - Table 7) show that the Tropical East Pacific mangrove province has decreased by about 6477.4 km^2 approximately -45.4% of its mangrove area during the last 50 years (1970-2020). Given that the change in geographic distribution is greater than 30% the ecosystem is assessed as **Vulnerable (VU)** under subcriterion A1.

Mangroves of the Tropical East Pacific	Area 2020* (km^2)	Area 1970** (km^2)	Net area Change (km^2)	% Net Area Change	Rate of change (%/year)
	7782	14259.4	-6477.4	-45.4	-0.91

*** Details on the methods and references used to estimate the mangrove area in 1970 are listed in Appendix 4.*

**Total mangrove area in 2020 is based on the Global Mangrove Watch Version 3 (GMW v3.0) dataset.*

Subcriterion A2 measures the change in ecosystem extent in any 50-year period, including from the present to the future: The Tropical East Pacific province mangroves show a net area change of -1.9% (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 (- 0.2%/year). The largest decrease in mangrove area in this time series occurred between 2019 and 2020, considering an estimate of -0.4%. Applying a linear regression to the area estimations between 1996 and 2020 we obtained a rate of change of -0.1%/year (Figure 3). Assuming this trend continues in the future, it is predicted that the extent of mangroves in the Tropical East Pacific province will change by -3.4% from 1996 to 2046; by -5.2% from 1996 to 2070; but by -3.3% from 2020 to 2070. Given that these predicted changes in mangrove extent are below the 30% risk threshold, the ecosystem is assessed as **Least Concern (LC)** under subcriterion A2.



Area estimates based on GMW v.3.0 - Bunting et al. (2022)

Figure 3. Projected extent of the Tropical East Pacific mangrove ecosystem to 2070. Circles represent the province mangrove area between 1996 and 2020 based on the GMW v3.0 dataset and equations in Bunting *et al.*, (2022). The solid line and shaded area are the linear regression and 95% confidence intervals. Squares show the Tropical East Pacific province predicted mangrove area for 2046 and 2070. It is important to note that an exponential model (proportional rate of decline) did not give a better fit to the data (R^2 = 0.9).

In the Peruvian case, the documentation of some new mangroves (such as La Bocana) is interesting; to date, there are no specific studies on growth or decline rates on mangroves for this country. A recent study shows the importance of evaluating these trends at a local scale, since some wetlands seem to grow despite human impacts, while others decrease, but at lower reduction rates than those known worldwide (Urbina *et al*., 2022). According to Murillo *et al*., (2022), the Colombian Pacific coast had 2343.45 ± 26.4 km^2, which decreased by approximately ~320 km^2 from 2004 to 2020.

Subcriterion A3 measures changes in mangrove area since 1750. Although there are local data, such as the case of the Colombian South Pacific, which according to paleoecological research (Behling *et al*., 1998; Vélez *et al*., 2001), there was a decrease in the area covered by mangroves in localities near Guapi (Sanquianga National Park), unfortunately, there are no reliable data on the mangrove extent for the entire province during this period, and therefore the ecosystem is classified as **Data Deficient (DD)** for this subcriterion.

Overall, the Tropical East Pacific mangrove ecosystem is assessed as **Vulnerable (VU)** under criterion A.

Criterion B: Restricted Geographic Distribution

Criterion B measures the risk of ecosystem collapse associated with restricted geographical distribution, based on standard metrics (Extent of Occurrence EOO, Area of Occupancy AOO and Threat-defined locations). These parameters were calculated based on the 2020 Tropical East Pacific province mangrove extent (GMW v3.0).

Province	Extent of Occurrence EOO (km^2)	Area of Occupancy (AOO)	Criterion B
The Tropical East Pacific	3,003,180.03	653	**LC**

For 2020, AOO and EOO were measured as 653 grid cells 10 x 10 km and 3,003,180.0 km^2, respectively. Excluding from the total of 986 those grid cells that contain patches of mangrove forest that account for less than 1% of the grid cell area (< 1 km^2), the AOO is measured as **653 10 x 10 km grid cells** (Figure 4, red grids).

Considering the EOO and AOO, and the very high number of threat-defined locations, that show no evidence of plausible catastrophic threats leading to the potential disappearance of mangroves over their entire extent in a short period of time, the Tropical East Pacific mangrove ecosystem is assessed as **Least Concern (LC)** under criterion B.

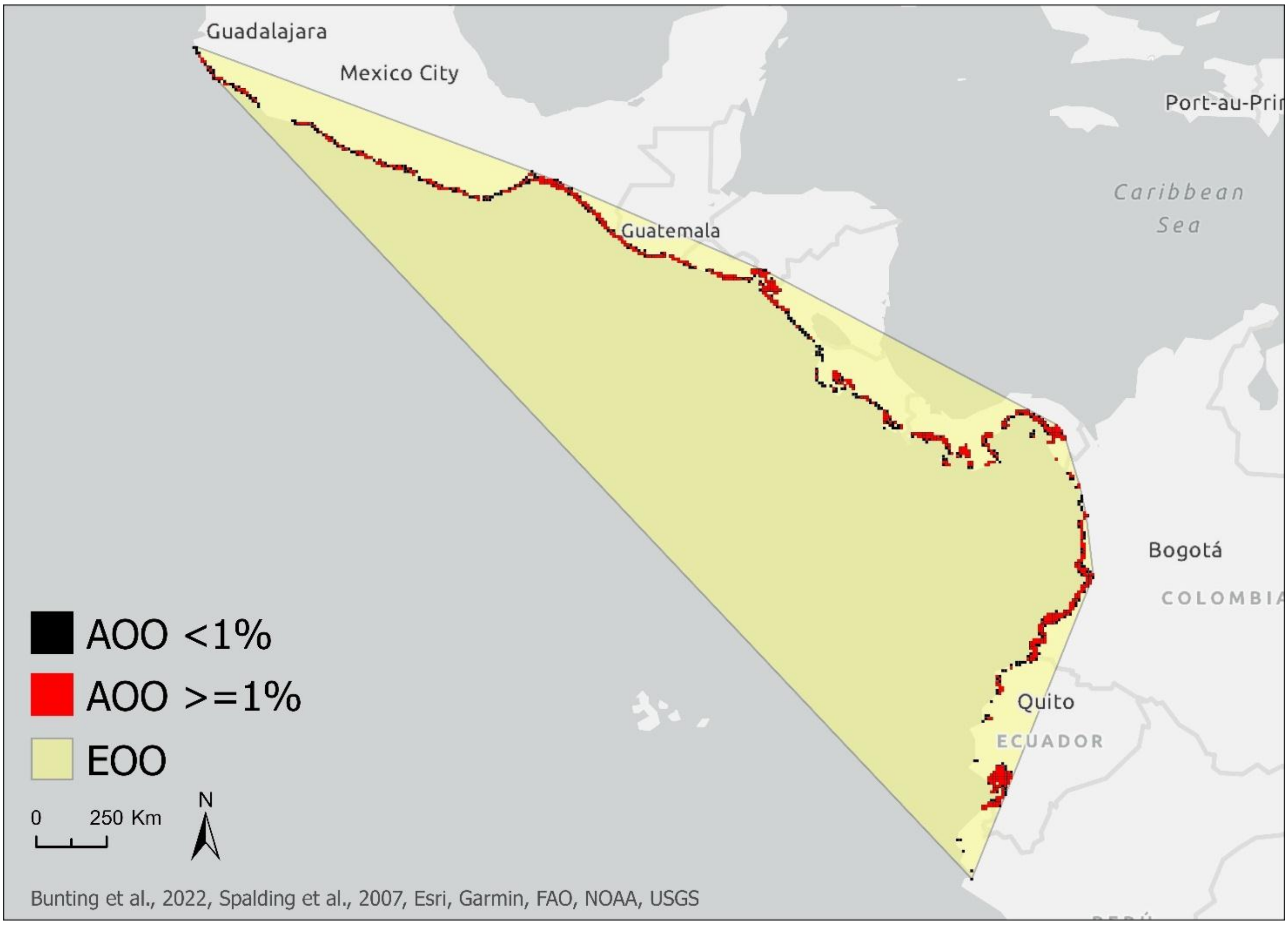


Figure 4. The Tropical East Pacific Coast Mangrove Extent Of Occurrence (EOO) and Area Of Occupancy (AOO) in 2020. Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al*., 2022). The red 10 x 10 km grids (n=653) are more than 1% covered by the ecosystem, and the black grids <1% (n= 333).

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 Tropical East 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. While mangrove ecosystems are reservoirs of pollutants from their watershed, and their degradation can be predicted based on the land use in the watershed, the percentage of impervious surface and the per capita area (Holland, 2004), no analysis of these characteristics is available to assess net degradation within the province by pollutant loading on a consistent basis. In this context, the impact of future sea level rise (SLR) on mangrove ecosystems is used 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

Tropical East Pacific mangrove ecosystem boundary using the spatial extent in 2010 (Giri *et al*., 2011) and assuming mangrove landward migration was not possible.

According to the results under an extreme sea-level rise scenario of 1.1 meters rise by 2100, the projected submerged area is ~ 9.8% 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 9.8% of the ecosystem extent will be affected by SLR, the Tropical East Pacific mangrove ecosystem is assessed as **Least Concern (LC)** for subcriterion C2.

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

Overall, the Tropical East Pacific 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 Tropical East Pacific province. This map is based on degradation metrics calculated from vegetation indices (NDVI, EVI, SAVI, NDMI) using Landsat time series (≈2000 and 2017). These indices represent vegetation greenness and moisture condition.

Mangrove degradation was calculated at a pixel scale (30m resolution), on areas intersecting with the 2017 mangrove extent map (GMW v2). Mangrove pixels were classified as degraded if two conditions were met: 1) at least 10 out of 12 degradation indices showed a decrease of more than 40% compared to the previous period; and 2) all twelve indices did not recover to within 20% of their pre-2000 value (detailed methods and data are available at: maps.oceanwealth.org/mangrove-restoration/). The decay in vegetation indices has been used to identify mangrove degradation and abrupt changes, including mangrove die-back events, clear-cutting, fire damage. and logging; as well as to track mangrove regeneration (Lovelock *et al.*, 2017; Santana, 2018; Murray *et al.*, 2020; Acuña-Piedra and Quesada-Román, 2021; Aljahdali *et al.*, 2021; Lee *et al.*, 2021; Veas-Ayala *et al.*, 2023). 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). 1% of the Tropical East Pacific mangrove area is classified as degraded, resulting in an average annual rate of degradation of 0.06%. Assuming this trend remains constant, +3.1% of the Topical East Pacific 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 Tropical East Pacific mangrove province is assessed as **Least Concern (LC)** under subcriterion D2b.

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

Overall, the Tropical East Pacific ecosystem remains **Least Concern (LC)** under criterion D.

Criterion E: Quantitative Risk

No model was used to quantitatively assess the risk of ecosystem collapse for this ecosystem; hence criterion E was **Not Evaluated (NE)**.

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)
	VU	**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 50 years period	**C3** Historical (1750)
	DD	**LC**	**DD**
D. Disruption of biotic processes	**D1** Past 50 years (1970)	**D2** Future or any 50 years period	**D3** Historical (1750)
	DD	**LC**	**DD**
E. Quantitative Risk analysis	**NE**		
OVERALL RISK CATEGORY	**VU**		

DD = Data Deficient; LC = Least Concern; NE = Not Evaluated, VU= Vulnerable

Overall, the status of the Tropical East Pacific mangrove ecosystem is assessed as **Vulnerable (VU).**

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Acknowledgments

The development of the Tropical East Pacific Red List of Mangrove Ecosystems was made possible by the IUCN SSC Mangrove Specialist Group and the Global Mangrove Alliance Science Working group, for their support in the delineation of the level 4 mangrove units that were the basis for this analysis. Special thanks to José Rafael Ferrer-Paris for his contribution to the production of the general ecosystem description template for the RLE mangrove assessments. We also wish to acknowledge Thomas Worthington for kindly providing the spatial data on mangrove degradation.

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7. Appendices

1. List of Key Mangrove Species

Table 2. List of true mangroves in the province (IUCN, 2022) lists the 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.

Table 2. List of true mangroves in the province (IUCN, 2022)

Class	Order	Family	Scientific name	RLTS category
Magnoliopsida	Ericales	Tetrameristaceae	Pelliciera rhizophorae	VU
Magnoliopsida	Lamiales	Acanthaceae	Avicennia bicolor	VU
Magnoliopsida	Lamiales	Acanthaceae	Avicennia germinans	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	Rhizophora racemosa	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	Rhizophora samoensis	NT
Magnoliopsida	Myrtales	Combretaceae	Laguncularia racemosa	LC

Other species recorded by other authors (Cornejo and Bonifaz, 2020; Brako and Zarucchi, 1993) in the province are listed in (Table 3). Although these species are not on the IUCN list for this province, they are considered in this evaluation.

Table 3. Other species of mangrove recorded in the province by others authors

Class	Order	Family	Scientific name	RLTS category
Magnoliopsida	Ericales	Tetrameristaceae	*Pelliciera benthamii*	NE
Magnoliopsida	Malpighiales	Rhizophoraceae	*Rhizophora mangle*	LC

2. List of Associated Species

Table 4 lists taxa 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" 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". We further filtered species with spatial point records in the GBIF (some species are excluded due to mismatches in taxonomic names, or lack of georeferenced records).

Table 4. List of species associated with the mangrove ecosystem (IUCN, 2022)

Class	Order	Family	Scientific name	RLTS category	Common name
Cycadopsida	Cycadales	Zamiaceae	*Zamia roezlii*	LC	Chigua
Magnoliopsida	Caryophyllales	Cactaceae	*Rhipsalis baccifera*	LC	Mistletoe cactus

Class	Order	Family	Scientific name	RLTS category	Common name
Magnoliopsida	Fabales	Fabaceae	*Mora oleifera*	VU	Nato mangrove, Cork oak
Magnoliopsida	Lamiales	Bignoniaceae	*Tabebuia palustris*	VU	Pigeon food
Magnoliopsida	Magnoliales	Annonaceae	*Annona glabra*	LC	Monkey apple
Magnoliopsida	Myrtales	Combretaceae	*Conocarpus erectus*	LC	Silver-leaved buttonwood
Polypodiopsida	Polypodiales	Pteridaceae	*Acrostichum danaeifolium*	LC	Beach fern
Gastropoda	Cycloneritida	Neritidae	*Vitta virginea*	LC	Virgin nerite
Gastropoda	Sorbeoconcha	Potamididae	*Cerithidea pliculosa*	LC	Horn shell
Actinopterygii	Albuliformes	Albulidae	*Albula vulpes*	NT	Bonefish
Actinopterygii	Atheriniformes	Atherinopsidae	*Atherinella chagresi*	LC	Chagres silverside
Actinopterygii	Cyprinodontiformes	Anablepidae	*Oxyzygonectes dovii*	LC	White-eye
Actinopterygii	Cyprinodontiformes	Poeciliidae	*Gambusia nicaraguensis*	LC	Nicaraguan mosquitofish
Actinopterygii	Cyprinodontiformes	Poeciliidae	*Poeciliopsis elongata*	NT	Elongate toothcarp
Actinopterygii	Cyprinodontiformes	Poeciliidae	*Poeciliopsis fasciata*	LC	San jeronimo livebearer
Actinopterygii	Cyprinodontiformes	Poeciliidae	*Poeciliopsis turrubarensis*	LC	Barred livebearer
Actinopterygii	Gobiiformes	Eleotridae	*Dormitator latifrons*	LC	Pacific fat sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Dormitator maculatus*	LC	Fat sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Eleotris picta*	LC	Spotted sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Erotelis smaragdus*	LC	Emerald sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Gobiomorus dormitor*	LC	Bigmouth sleeper
Actinopterygii	Gobiiformes	Eleotridae	*Guavina guavina*	LC	Guavina
Actinopterygii	Gobiiformes	Eleotridae	*Hemieleotris latifasciata*	LC	Guabinita
Actinopterygii	Gobiiformes	Gobiidae	*Lophogobius cyprinoides*	LC	Crested goby
Actinopterygii	Gobiiformes	Gobiidae	*Microgobius tabogensis*	LC	Taboga goby
Actinopterygii	Gobiiformes	Gobiidae	*Sicydium gymnogaster*	LC	Smoothbelly goby
Actinopterygii	Perciformes	Blenniidae	*Hypsoblennius maculipinna*	DD	Potted fin chub
Actinopterygii	Perciformes	Carangidae	*Chloroscombrus orqueta*	LC	Pacific bumper
Actinopterygii	Perciformes	Centropomidae	*Centropomus mexicanus*	LC	Largescale fat snook
Actinopterygii	Perciformes	Centropomidae	*Centropomus nigrescens*	LC	Black robalo
Actinopterygii	Perciformes	Centropomidae	*Centropomus armatus*	LC	Armed snook
Actinopterygii	Perciformes	Cichlidae	*Mayaheros urophthalmus*	LC	Mayan cichlid
Actinopterygii	Perciformes	Dactyloscopidae	*Dactyloscopus amnis*	LC	Riverine stargazer
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus quinquefasciatus*	DD	Pacific goliath grouper
Actinopterygii	Perciformes	Epinephelidae	*Mycteroperca*	DD	Broomtail grouper

Class	Order	Family	Scientific name	RLTS category	Common name
			xenarcha		
Actinopterygii	Perciformes	Haemulidae	*Haemulon steindachneri*	LC	Latin grunt
Actinopterygii	Perciformes	Sciaenidae	*Bairdiella armata*	LC	Armed croaker
Actinopterygii	Perciformes	Sciaenidae	*Bairdiella icistia*	LC	Ronco croaker
Actinopterygii	Perciformes	Sciaenidae	*Elattarchus archidium*	LC	Bluestreak drum
Actinopterygii	Perciformes	Sciaenidae	*Larimus acclivis*	LC	Steeplined drum
Actinopterygii	Perciformes	Sciaenidae	*Larimus argenteus*	LC	Silver drum
Actinopterygii	Perciformes	Sciaenidae	*Larimus effulgens*	LC	Shining drum
Actinopterygii	Perciformes	Sciaenidae	*Menticirrhus elongatus*	LC	Pacific kingcroaker
Actinopterygii	Perciformes	Sciaenidae	*Menticirrhus nasus*	LC	Highfin king croaker
Actinopterygii	Perciformes	Sciaenidae	*Menticirrhus ophicephalus*	LC	Snakehead kingcroaker
Actinopterygii	Perciformes	Sciaenidae	*Menticirrhus panamensis*	LC	Panama kingcroaker
Actinopterygii	Perciformes	Sciaenidae	*Nebris occidentalis*	LC	Pacific smalleye croaker
Actinopterygii	Perciformes	Sciaenidae	*Ophioscion scierus*	LC	Point-tuza croaker
Actinopterygii	Perciformes	Sciaenidae	*Ophioscion simulus*	LC	Snub-nosed croaker
Actinopterygii	Perciformes	Sciaenidae	*Ophioscion typicus*	LC	Point-nosed croaker
Actinopterygii	Perciformes	Sciaenidae	*Ophioscion vermicularis*	LC	Vermiculated croaker
Actinopterygii	Perciformes	Sciaenidae	*Paralonchurus dumerilii*	LC	Suco croaker
Actinopterygii	Perciformes	Sciaenidae	*Paralonchurus goodei*	LC	Goode croaker
Actinopterygii	Perciformes	Sciaenidae	*Stellifer ephelis*	LC	Swift stardrum
Actinopterygii	Perciformes	Sciaenidae	*Stellifer fuerthii*	LC	White stardrum
Actinopterygii	Perciformes	Sciaenidae	*Stellifer illecebrosus*	LC	Silver stardrum
Actinopterygii	Perciformes	Sciaenidae	*Stellifer mancorensis*	LC	Smooth stardrum
Actinopterygii	Perciformes	Sciaenidae	*Stellifer melanocheir*	LC	Black stardrum
Actinopterygii	Perciformes	Sciaenidae	*Stellifer oscitans*	LC	Yawning stardrum
Actinopterygii	Perciformes	Sciaenidae	*Stellifer pizarroensis*	LC	Pizzaro stardrum
Actinopterygii	Perciformes	Sciaenidae	*Umbrina analis*	LC	Longspine drum
Actinopterygii	Perciformes	Sciaenidae	*Umbrina dorsalis*	LC	Longfin drum
Actinopterygii	Perciformes	Uranoscopidae	*Astroscopus zephyreus*	LC	Pacific stargazer
Actinopterygii	Perciformes	Uranoscopidae	*Kathetostoma averruncus*	LC	Smooth stargazer
Actinopterygii	Pleuronectiformes	Achiridae	*Achirus mazatlanus*	LC	Mazatlan sole
Actinopterygii	Pleuronectiformes	Achiridae	*Trinectes fonsecensis*	LC	Spottedfin sole
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Cyclopsetta panamensis*	LC	Panamanian flounder
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Cyclopsetta querna*	LC	Toothed flounder
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Etropus ectenes*	LC	Sole flounder

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Hippoglossina tetrophthalma*	LC	Fourspot flounder
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Syacium ovale*	LC	Oval flounder
Actinopterygii	Mugiliformes	Mugilidae	*Xenomugil thoburni*	LC	Mugil thoburni
Actinopterygii	Pleuronectiformes	Cynoglossidae	*Symphurus chabanaudi*	LC	Chabanaud's tonguefish
Actinopterygii	Pleuronectiformes	Cynoglossidae	*Symphurus melanurus*	LC	Drab tonguefish
Actinopterygii	Pleuronectiformes	Achiridae	*Achirus klunzingeri*	LC	Brown sole
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Sphoeroides annulatus*	LC	Bullseye puffer
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Negaprion brevirostris*	VU	Lemon shark
Chondrichthyes	Myliobatiformes	Urotrygonidae	*Urobatis tumbesensis*	VU	Tumbes round ray
Chondrichthyes	Myliobatiformes	Urotrygonidae	*Urotrygon chilensis*	NT	Chilean round ray
Chondrichthyes	Myliobatiformes	Urotrygonidae	*Urotrygon nana*	NT	Dwarf round ray
Chondrichthyes	Myliobatiformes	Potamotrygonidae	*Styracura pacifica*	VU	Pacific chupare
Chondrichthyes	Orectolobiformes	Ginglymostomatidae	*Ginglymostoma unami*	EN	Pacific nurse shark
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis pristis*	CR	Largetooth sawfish
Amphibia	Anura	Leptodactylidae	*Leptodactylus melanonotus*	LC	Sabinal frog
Reptilia	Crocodylia	Crocodylidae	*Crocodylus acutus*	VU	American crocodile
Reptilia	Squamata	Boidae	*Corallus ruschenbergerii*	LC	Ruschenberger's tree boa
Reptilia	Squamata	Colubridae	*Chironius flavopictus*	DD	Yellow machete blade
Reptilia	Squamata	Iguanidae	*Ctenosaura acanthura*	LC	Veracruz Spiny-tailed Iguana
Reptilia	Squamata	Teiidae	*Dicrodon heterolepis*	LC	Ecuador desert tegu
Aves	Accipitriformes	Accipitridae	*Busarellus nigricollis*	LC	Black-collared hawk
Aves	Accipitriformes	Accipitridae	*Buteo brachyurus*	LC	Short-tailed hawk
Aves	Accipitriformes	Accipitridae	*Buteogallus meridionalis*	LC	Savanna hawk
Aves	Accipitriformes	Accipitridae	*Buteogallus urubitinga*	LC	Great black hawk
Aves	Accipitriformes	Accipitridae	*Elanoides forficatus*	LC	Swallow-tailed kite
Aves	Accipitriformes	Accipitridae	*Ictinia plumbea*	LC	Plumbeous kite
Aves	Anseriformes	Anatidae	*Nomonyx dominicus*	LC	Masked duck
Aves	Caprimulgiformes	Caprimulgidae	*Nyctidromus albicollis*	LC	Pauraque
Aves	Caprimulgiformes	Nyctibiidae	*Nyctibius griseus*	LC	Common potoo
Aves	Caprimulgiformes	Trochilidae	*Amazilia boucardi*	EN	Mangrove hummingbird
Aves	Caprimulgiformes	Trochilidae	*Amazilia tzacatl*	LC	Rufous-tailed hummingbird
Aves	Caprimulgiformes	Trochilidae	*Anthracothorax prevostii*	LC	Green-breasted mango
Aves	Caprimulgiformes	Trochilidae	*Chrysuronia coeruleogularis*	LC	Sapphire-throated hummingbird

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Caprimulgiformes	Trochilidae	*Chrysuronia humboldtii*	LC	Humboldt's hummingbird
Aves	Caprimulgiformes	Trochilidae	*Phaeochroa cuvierii*	LC	Scaly-breasted Sabrewing
Aves	Cathartiformes	Cathartidae	*Cathartes burrovianus*	LC	Lesser yellow-headed vulture
Aves	Ciconiiformes	Ciconiidae	*Mycteria americana*	LC	Wood stork
Aves	Columbiformes	Columbidae	*Patagioenas cayennensis*	LC	Pale-vented pigeon
Aves	Columbiformes	Columbidae	*Zenaida asiatica*	LC	White-winged dove
Aves	Columbiformes	Columbidae	*Zenaida auriculata*	LC	Eared dove
Aves	Coraciiformes	Alcedinidae	*Chloroceryle aenea*	LC	American pygmy-kingfisher
Aves	Coraciiformes	Alcedinidae	*Chloroceryle amazona*	LC	Amazon kingfisher
Aves	Coraciiformes	Alcedinidae	*Chloroceryle americana*	LC	Green kingfisher
Aves	Coraciiformes	Alcedinidae	*Chloroceryle inda*	LC	Green-and-rufous kingfisher
Aves	Coraciiformes	Alcedinidae	*Megaceryle alcyon*	LC	Belted kingfisher
Aves	Coraciiformes	Alcedinidae	*Megaceryle torquata*	LC	Ringed kingfisher
Aves	Cuculiformes	Cuculidae	*Coccyzus melacoryphus*	LC	Dark-billed cuckoo
Aves	Cuculiformes	Cuculidae	*Coccyzus minor*	LC	Mangrove cuckoo
Aves	Cuculiformes	Cuculidae	*Crotophaga ani*	LC	Smooth-billed ani
Aves	Cuculiformes	Cuculidae	*Crotophaga major*	LC	Greater ani
Aves	Cuculiformes	Cuculidae	*Piaya cayana*	LC	Common squirrel-cuckoo
Aves	Falconiformes	Falconidae	*Micrastur semitorquatus*	LC	Collared forest-falcon
Aves	Galliformes	Cracidae	*Ortalis leucogastra*	LC	White-bellied Chachalaca
Aves	Galliformes	Cracidae	*Ortalis poliocephala*	LC	West mexican chachalaca
Aves	Galliformes	Cracidae	*Ortalis vetula*	LC	Plain chachalaca
Aves	Gruiformes	Aramidae	*Aramus guarauna*	LC	Limpkin
Aves	Gruiformes	Rallidae	*Aramides axillaris*	LC	Rufous-necked wood-rail
Aves	Gruiformes	Rallidae	*Aramides wolfi*	VU	Brown wood-rail
Aves	Gruiformes	Rallidae	*Rallus longirostris*	LC	Mangrove rail
Aves	Passeriformes	Corvidae	*Cyanocorax sanblasianus*	LC	San blas jay
Aves	Passeriformes	Cotingidae	*Carpodectes antoniae*	NT	Yellow-billed cotinga
Aves	Passeriformes	Cotingidae	*Carpodectes hopkei*	LC	Black-tipped cotinga
Aves	Passeriformes	Furnariidae	*Dendrocincla anabatina*	LC	Tawny-winged woodcreeper
Aves	Passeriformes	Furnariidae	*Dendrocolaptes sancthithomae*	LC	Western barred woodcreeper
Aves	Passeriformes	Furnariidae	*Lepidocolaptes souleyetii*	LC	Streak-headed woodcreeper
Aves	Passeriformes	Furnariidae	*Xiphorhynchus flavigaster*	LC	Ivory-billed woodcreeper

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Passeriformes	Furnariidae	*Xiphorhynchus lachrymosus*	LC	Black-striped woodcreeper
Aves	Passeriformes	Furnariidae	*Xiphorhynchus susurrans*	LC	Cocoa woodcreeper
Aves	Passeriformes	Hirundinidae	*Stelgidopteryx serripennis*	LC	Northern rough-winged swallow
Aves	Passeriformes	Hirundinidae	*Tachycineta albilinea*	LC	Mangrove swallow
Aves	Passeriformes	Icteridae	*Icterus mesomelas*	LC	Yellow-tailed oriole
Aves	Passeriformes	Parulidae	*Geothlypis trichas*	LC	Common yellowthroat
Aves	Passeriformes	Parulidae	*Helmitheros vermivorum*	LC	Worm-eating warbler
Aves	Passeriformes	Parulidae	*Parkesia noveboracensis*	LC	Northern waterthrush
Aves	Passeriformes	Parulidae	*Protonotaria citrea*	LC	Prothonotary warbler
Aves	Passeriformes	Parulidae	*Setophaga dominica*	LC	Yellow-throated warbler
Aves	Passeriformes	Parulidae	*Setophaga ruticilla*	LC	American redstart
Aves	Passeriformes	Pipridae	*Chiroxiphia linearis*	LC	Long-tailed manakin
Aves	Passeriformes	Polioptilidae	*Polioptila caerulea*	LC	Blue-grey gnatcatcher
Aves	Passeriformes	Thamnophilidae	*Sclateria naevia*	LC	Silvered antbird
Aves	Passeriformes	Thamnophilidae	*Thamnophilus bernardi*	LC	Collared antshrike
Aves	Passeriformes	Thamnophilidae	*Thamnophilus bridgesi*	LC	Black-hooded antshrike
Aves	Passeriformes	Tityridae	*Pachyramphus cinnamomeus*	LC	Cinnamon becard
Aves	Passeriformes	Tityridae	*Pachyramphus polychopterus*	LC	White-winged becard
Aves	Passeriformes	Troglodytidae	*Campylorhynchus capistratus*	LC	Rufous-backed wren
Aves	Passeriformes	Troglodytidae	*Campylorhynchus humilis*	LC	Sclater's wren
Aves	Passeriformes	Troglodytidae	*Cantorchilus leucotis*	LC	Buff-breasted wren
Aves	Passeriformes	Troglodytidae	*Thryophilus pleurostictus*	LC	Banded wren
Aves	Passeriformes	Tyrannidae	*Capsiempis flaveola*	LC	Yellow tyrannulet
Aves	Passeriformes	Tyrannidae	*Contopus punensis*	LC	Western tropical pewee
Aves	Passeriformes	Tyrannidae	*Myiarchus phaeocephalus*	LC	Sooty-crowned flycatcher
Aves	Passeriformes	Tyrannidae	*Myiarchus tyrannulus*	LC	Brown-crested Flycatcher
Aves	Passeriformes	Tyrannidae	*Phaeomyias murina*	LC	Mouse-colored tyrannulet
Aves	Passeriformes	Tyrannidae	*Sublegatus arenarum*	LC	Northern scrub-flycatcher
Aves	Passeriformes	Tyrannidae	*Tolmomyias flaviventris*	LC	Ochre-lored flatbill
Aves	Passeriformes	Tyrannidae	*Tyrannus dominicensis*	LC	Grey kingbird
Aves	Passeriformes	Tyrannidae	*Tyrannus savana*	LC	Fork-tailed flycatcher
Aves	Passeriformes	Vireonidae	*Cyclarhis gujanensis*	LC	Rufous-browed peppershrike

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Passeriformes	Vireonidae	*Hylophilus viridiflavus*	LC	Yellow-green greenlet
Aves	Passeriformes	Vireonidae	*Vireo flavoviridis*	LC	Yellow-green vireo
Aves	Passeriformes	Vireonidae	*Vireo pallens*	LC	Mangrove vireo
Aves	Pelecaniformes	Ardeidae	*Ardea herodias*	LC	Great blue heron
Aves	Pelecaniformes	Ardeidae	*Butorides striata*	LC	Green-backed heron
Aves	Pelecaniformes	Ardeidae	*Cochlearius cochlearius*	LC	Boat-billed heron
Aves	Pelecaniformes	Ardeidae	*Egretta caerulea*	LC	Little blue heron
Aves	Pelecaniformes	Ardeidae	*Egretta rufescens*	NT	Reddish egret
Aves	Pelecaniformes	Ardeidae	*Egretta tricolor*	LC	Tricolored heron
Aves	Pelecaniformes	Ardeidae	*Ixobrychus exilis*	LC	Least bittern
Aves	Pelecaniformes	Ardeidae	*Tigrisoma lineatum*	LC	Rufescent tiger-heron
Aves	Pelecaniformes	Threskiornithidae	*Eudocimus albus*	LC	White ibis
Aves	Piciformes	Bucconidae	*Notharchus hyperrhynchus*	LC	White-necked puffbird
Aves	Piciformes	Picidae	*Campephilus guatemalensis*	LC	Pale-billed woodpecker
Aves	Piciformes	Picidae	*Colaptes punctigula*	LC	Spot-breasted woodpecker
Aves	Piciformes	Picidae	*Colaptes rubiginosus*	LC	Golden-olive woodpecker
Aves	Piciformes	Picidae	*Dryobates scalaris*	LC	Ladder-backed woodpecker
Aves	Piciformes	Picidae	*Melanerpes rubricapillus*	LC	Red-crowned woodpecker
Aves	Piciformes	Ramphastidae	*Ramphastos sulfuratus*	NT	Keel-billed toucan
Aves	Psittaciformes	Psittacidae	*Amazona albifrons*	LC	White-fronted amazon
Aves	Psittaciformes	Psittacidae	*Amazona auropalliata*	CR	Yellow-naped amazon
Aves	Psittaciformes	Psittacidae	*Amazona finschi*	EN	Lilac-crowned amazon
Aves	Psittaciformes	Psittacidae	*Amazona lilacina*	CR	Lilacine amazon
Aves	Psittaciformes	Psittacidae	*Amazona oratrix*	EN	Yellow-headed amazon
Aves	Psittaciformes	Psittacidae	*Ara macao*	LC	Scarlet macaw
Aves	Strigiformes	Strigidae	*Megascops cooperi*	LC	Pacific screech-owl
Aves	Suliformes	Fregatidae	*Fregata magnificens*	LC	Magnificent frigatebird
Aves	Suliformes	Fregatidae	*Fregata minor*	LC	Great frigatebird
Aves	Trogoniformes	Trogonidae	*Trogon citreolus*	LC	Citreoline trogon
Aves	Trogoniformes	Trogonidae	*Trogon massena*	LC	Slaty-tailed trogon
Aves	Trogoniformes	Trogonidae	*Trogon melanocephalus*	LC	Black-headed trogon
Aves	Trogoniformes	Trogonidae	*Trogon melanurus*	LC	Black-tailed trogon
Aves	Cuculiformes	Cuculidae	*Coccycua minuta*	LC	Little cuckoo
Aves	Cuculiformes	Cuculidae	*Piaya mexicana*	LC	Mexican squirrel-cuckoo
Aves	Gruiformes	Rallidae	*Aramides cajaneus*	LC	Grey-cowled wood-rail
Aves	Passeriformes	Furnariidae	*Dendroplex picus*	LC	Straight-billed woodcreeper

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Passeriformes	Tyrannidae	*Contopus bogotensis*	LC	Northern tropical pewee
Aves	Passeriformes	Tyrannidae	*Phaeomyias tumbezana*	LC	Tumbes tyrannulet
Aves	Passeriformes	Tyrannidae	*Philohydor lictor*	LC	Lesser kiskadee
Aves	Piciformes	Bucconidae	*Notharchus subtectus*	LC	Lesser pied puffbird
Aves	Piciformes	Picidae	*Colaptes cafer*	LC	Red-shafted flicker
Aves	Strigiformes	Strigidae	*Ciccaba nigrolineata*	LC	Black-and-white owl
Mammalia	Carnivora	Felidae	*Leopardus pardalis*	LC	Ocelot
Mammalia	Carnivora	Felidae	*Panthera onca*	NT	Jaguar
Mammalia	Carnivora	Procyonidae	*Procyon cancrivorus*	LC	Crab-eating raccoon
Mammalia	Carnivora	Procyonidae	*Procyon lotor*	LC	Northern raccoon
Mammalia	Cetartiodactyla	Tayassuidae	*Pecari tajacu*	LC	Collared peccary
Mammalia	Cetartiodactyla	Tayassuidae	*Tayassu pecari*	VU	White-lipped peccary
Mammalia	Chiroptera	Noctilionidae	*Noctilio leporinus*	LC	Greater bulldog bat
Mammalia	Didelphimorphia	Didelphidae	*Didelphis marsupialis*	LC	Common opossum
Mammalia	Didelphimorphia	Didelphidae	*Didelphis virginiana*	LC	Virginia opossum
Mammalia	Didelphimorphia	Didelphidae	*Metachirus nudicaudatus*	LC	Brown four-eyed opossum
Mammalia	Pilosa	Bradypodidae	*Bradypus variegatus*	LC	Brown-throated Sloth
Mammalia	Pilosa	Cyclopedidae	*Cyclopes didactylus*	LC	Silky anteater
Mammalia	Pilosa	Myrmecophagidae	*Tamandua mexicana*	LC	Northern tamandua
Mammalia	Primates	Aotidae	*Aotus zonalis*	NT	Panamanian night monkey
Mammalia	Primates	Atelidae	*Alouatta palliata*	VU	Mantled howler monkey

3. Climate variables

A geospatial analysis of the NASA POWER project database (The data was obtained from the National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (POWER) Project funded through the NASA Earth Science/Applied Science Program.) shows that climate variables between 1981 and 2022 at 40 representative sites in the province (Table 5).

Table 5. Estimates of annual averages of precipitation, temperature, and relative humidity between 1981 and 2022 for selected locations within the province (the data was obtained from the POWER Project's Hourly 2.0.0 version on 2024/05/11).

Location	Latitude	Longitude	Country	Annual Average Precipitation (mm)	Annual Average Temperature (C)	Annual average relative humidity (%)
Puerto Villarta	20.5931	-105.2272	Mexico	1202.4	22.4	68.1

Location	Latitude	Longitude	Country	Annual Average Precipitation (mm)	Annual Average Temperature (C)	Annual average relative humidity (%)
Acapulco	16.8761	-99.8617	Mexico	1103.5	25.5	72.4
Laguna Chautenco	16.2103	-95.0428	Mexico	1103.5	25.0	72.4
Chiapas	14.8000	-92.4988	Mexico	2147.2	25.4	75.7
Champerico	14.2895	-91.9082	Guatemala	1770.9	25.6	77.0
San Jose	13.9239	-90.8886	Guatemala	1141.4	26.2	72.7
Moyuta	13.7946	-90.2033	Guatemala	963.7	24.8	72.2
Chiltuipan	13.5064	-89.4507	El Salvador	1141.1	27.0	71.3
Usulutan	13.1787	-88.4144	El Salvador	1083.2	28.3	70.5
La Union	13.3408	-87.8570	El Salvador	956.6	27.4	66.0
San Lorenzo	13.3819	-87.4509	Honduras	940.8	27.6	63.7
Estero real	12.9446	-87.3184	Nicaragua	1022.0	28.9	67.2
Estero Padre Ramos	12.7826	-87.4928	Nicaragua	1041.0	28.6	65.9
Isla Juan Venado	12.3118	-86.9459	Nicaragua	1290.0	28.2	72.7
Nagarote	12.1990	-86.7623	Nicaragua	1171.4	26.6	75.9
Parque Nacional Santa Rosa	10.8870	-85.8068	Costa Rica	1225.3	27.6	73.0
Cabo Velas	10.3606	-85.8589	Costa Rica	1780.2	27.7	78.2
Puntarenas	9.5869	-85.1201	Costa Rica	1035.7	25.2	78.3
Cabo Nacional Palo Verde	10.2890	-85.2423	Costa Rica	2405.1	27.3	81.5
Parque Nacional Corcovado	8.4551	-83.5449	Costa Rica	2636.4	27.5	80.6
Parque Nacional Isla Coiba	7.4269	-81.7789	Panama	2117.0	27.3	81.2
Leones	7.7318	-81.1156	Panama	2236.4	26.9	83.6
Parque Nacional Cerro Haya	7.2225	-80.8643	Panama	1684.8	26.4	82.7
Cenegon de mangle	8.0786	-80.4798	Panama	1917.8	26.3	83.5
Punta Chame	8.6479	-79.7052	Panama	1795.4	26.5	85.0
Bahia Piña	8.4069	-78.2482	Panama	3612.9	25.5	88.2
Jurado	6.9460	-77.6616	Colombia	4126.0	25.4	89.9
Bahia Solano	6.2264	-77.4027	Colombia	5799.2	26.1	87.7
Nuqui	6.0045	-77.3578	Colombia	5847.5	26.0	87.8

Location	Latitude	Longitude	Country	Annual Average Precipitation (mm)	Annual Average Temperature (C)	Annual average relative humidity (%)
Buenaventura	3.8592	-77.1727	Colombia	1729.2	23.6	87.6
Timbiqui	2.8063	-77.7399	Colombia	1971.7	25.0	86.7
San Andres de Tumaco	1.7744	-78.8742	Colombia	1086.0	26.1	81.9
La Tola	1.1896	-79.0706	Ecuador	1367.0	25.4	81.7
Esmeraldas	0.9836	-79.6543	Ecuador	1227.7	24.9	82.4
Quingue	0.7378	-80.0924	Ecuador	1310.2	24.8	80.2
Pedernales	0.0402	-80.0841	Ecuador	606.3	24.5	82.3
Bahia de Caraquez	-0.6341	-80.4425	Ecuador	609.3	24.2	76.1
Salango	-1.5814	-80.8312	Ecuador	344.5	24.5	74.0
Tumbes	-3.5171	-80.4412	Peru	112.9	22.8	76.0

4. National Estimates for subcriterion A1

To calculate the mangrove area in 1970 the trend functions established by FAO (2003) were used (Table 6) including a linear adjustment for Costa Rica and Nicaragua. In addition, the relationship between the total surfaces per country and what they contribute within the province was considered, through the proportions between 1996 and 2020 of the GMW V3.0. Although, these calculations may be imprecise due to the diversity of methods and techniques used in the different studies compiled, it was a relevant input to approximately estimate the extent of mangrove cover in that year.

Table 6. Estimates of mangrove cover in km^2 for the year 1970 derived from national studies (FAO, 2003).

Country	Mangrove area in 1970	Mangrove area in 1970 within the province	Reference
Colombia	4811.0	3349.5	Calculations derived from: 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.
Costa Rica	386.8	386.6	
Ecuador	2248.3	2177.0	
El Salvador	587.5	587.5	
Guatemala	219.0	211.9	
Honduras	2095.5	1261.4	
Mexico	7426.3	782.4	
Nicaragua	4006.0	2074.8	
Panama	3464.9	3299.1	
Peru	129.3	129.3	
Total	**25374.5**	**14259.4**	

The total extension of mangroves by country is shown in Table 7, as well as what it occupies within the province. Together with the data calculated for 1970, these data served to obtain an a priori estimate of the changes that have occurred in the last 50 years. However, using estimates of mangrove area from different sources may introduce uncertainty (Friess and Webb, 2014). Therefore, these estimates should be considered only indicative. Also, some figures resulting from national mapping are presented as additional information.

Table 7. Estimates of mangrove area in km2 for 2020 from the Global Mangrove Watch Version 3 (GMW v3.0) dataset are presented, and estimates of mangrove cover from national efforts are also listed.

Year	GMW v3.0		National estimates	
	Country total	Within province	Country total	Within province
	2020		2020	
Colombia[3]	2807.7	1972	2792.12	2008.46
Costa Rica[4]	371.2	371	418	N/A
Ecuador	1535.7	1485.6	N/A	N/A
El Salvador	370.8	370.8	N/A	N/A
Guatemala	249.5	241.1	N/A	N/A
Honduras[4]	606.5	362.5	628	N/A
Mexico[2]	10059	1075.7	10413.4	910.6
Nicaragua	749.1	386.2	N/A	N/A
Panama[5]	1535.8	1462.2	1860.6	N/A
Peru	54.9	54.9	N/A	N/A
				N/A = Not Available

It's important to mention that this cartographic information for the different countries in the province is based on different methodologies, boundaries, and sources. As such, these data are for information purposes only and do not represent an exact comparison between them.

5. National estimates for subcriterion C2

The risk maps related to sea-level rise on the coast of Colombia correspond to the projection scenarios with the most forcing in the CMIP 5. These scenarios project sea-level rise levels of 18 cm by 2040, 29 cm by 2070, and 40 cm by 2100. National estimates, made in 2017 by INVEMAR and IDEAM, indicate mangrove areas exposed to sea-level rise scenarios in square kilometers for the study province during the years 2040, 2070, and 2100 (INVEMAR, IDEAM, 2017). These calculations were performed using the Lambert Azimuthal projection (Table 8).

Table 8. National assessment of exposure in km2 of mangrove ecosystems to sea level rise on the Tropical East Pacific.

Country	Scenario 2040	Scenario 2070	Scenario 2100	Reference
Colombia	1748.2	2414.7	2449.9	INVEMAR, IDEAM. (2017). Elaboración del análisis de vulnerabilidad marino costero e insular ante el cambio climático para el país. Informe Técnico Final (ITF)- 001. 256 p.

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[2] Mangrove national distribution of Mexico (CONABIO 2021)

[3] The area reported for Colombia for 2020 was obtained from the latest edition of the national mangrove map. published on March 22. 2023. by the Institute of Marine and Coastal Research (INVEMAR). It also provides more detailed information for the insular Caribbean. specifically in the archipelago of San Andrés. Providencia. and Santa Catalina (INVEMAR, 2023).

[4] Data for 2020: UNESDOC Digital library and national cartographic data. https://unesdoc.unesco.org/

[5] Resolution No. DM-0148-2022 that approves the map of forest cover and land use 2021. Ministerio de Ambiente, República de Panamá.