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Mangroves of the Arabian (Persian) Gulf

VU

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Abstract

Mangroves of the Arabian (Persian) Gulf is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology). It includes the marine ecoregions of the Arabian (Persian) Gulf, Gulf of Aden, Gulf of Oman, Western Arabian Sea and Western India (Asia). Mangroves of the Arabian (Persian) Gulf occupy sheltered intertidal lagoons along coastlines and offshore islands, occupying various shore types including highly organic soft sediments, sandy soils, and consolidated hard substrata. The biota is characterized by four species of true mangroves: *Rhizophora mucronata*, *Avicennia marina*, *Aegiceras corniculatum*, and *Ceriops tagal*. Of these species, *R. mucronata* and *A. marina* are found along the northern Arabian Gulf and Western Asia, while *Aegiceras corniculatum* and *Ceriops tagal* occur only in Western Asia (Iran and Balochistan Province of Pakistan), *Avicennia marina* is widespread throughout this entire ecoregion, including the southern and western Arabian Gulf.

The mapped extent of mangroves in 2020 was 209.5 km^2, representing 0.1 % of the global mangrove area. About 47 % occupy the southern coastline of the United Arab Emirates and 39 % the northern coastline of Iran. However, there is uncertainty about mapped extent in 1970 based on available studies. The mangrove net area change has been -14.3 % since 1996. However, there have been increases in patches largely due to plantation efforts. If this decline trend continues, an overall change of -45.0% is projected over the next 50 years. Under a high sea-level rise scenario (IPCC RCP8.5) ≈16.1 % of the Arabian Gulf mangroves would be submerged by 2060. Moreover, 1.1% of the province's mangrove ecosystem is undergoing degradation, with the potential to increase to 3.3% within a 50-year period, based on a vegetation index decay analysis. Overall, the Arabian (Persian) Gulf mangrove ecosystem is assessed as **Vulnerable (VU).**

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

Ecosystem classification:
MFT1.2 Intertidal forests and shrublands

Assessment's distribution:
The Arabian (Persian) Gulf province

Summary of the assessment:

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

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

Mangroves of the Arabian (Persian) Gulf

VU

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_19 Mangroves of the Arabian (Persian) Gulf

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

Avicennia marina mangrove and rocky shoreline of the Southern Arabian (Persian) Gulf, United Arab Emirates (Photo credit: Amna Almansoori).

[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.

Mangroves and saltmarshes along intertidal zone of Southern Arabian (Persian) Gulf, United Arab Emirates (Photo credit: Amna Almansoori).

Planted Rhizophora mucronata trees together with natural Avicennia marina mangrove near Jiwani in Western Balochistan Province, Pakistan (Photo credit: Donald Macintosh).

2. Ecosystem Description

Spatial distribution

The Mangroves of the Arabian (Persian) Gulf includes intertidal forest and shrublands of the marine ecoregions of Arabian (Persian) Gulf, Gulf of Aden, Gulf of Oman, Western Arabian Sea and Western India (Spalding *et al.*, 2007) (Figure 1). The interior Arabian (Persian) Gulf is bordered by eight counties: Bahrain, Iran, Kuwait, Iraq, Oman, Qatar, Saudi Arabia, and United Arab Emirates, while the Western Arabian Sea and Western India ecoregions comprise of Oman, Iran and Pakistan. According to the literature, there is also a small area of mangroves, approximately 0.01 km^2, in the Yemeni Governorate of Al Maharah (Nagi *et al.*, 2012). However, due to the lack of spatial data regarding its exact location, it was not included in the assessment of the mangroves of the Arabia/Persian Gulf.

Mangroves of the Arabian (Persian) Gulf occur as fragmented monospecific stands of once a much larger expense (Sheppard *et al*., 1992). Of the total interior Arabian (Persian) Gulf mangroves extent, approximately 47 % are situated along the Southern coastline of the United Arab Emirates and approximately 39 % along the Northern coastline of Iran, with marginal habitat increases along Southern coastline largely due to reforestation and plantation efforts (Almahasheer, 2018). Using 25 satellite imagery recently acquired from Landsat 8 data for the year 2017. This study found about 165 km^2 of fragmented scattered mangroves along the Arabian (Persian) Gulf, mostly intense in the United Arab Emirates (Almahasheer, 2018). Earlier records of the Arabian (Persian) Gulf Southern interior coastline (United Arab Emirates) indicated an extent of 35 km^2 (year 1980) and 41 km^2 (year 2005) (FAO, 2007), while recent records using very high-resolution imagery from WorldView-2 recorded 57.8 km^2 (EAD, 2020), where plantation projects have likely played a significant role in increasing their cover over the years (Almahasheer, 2018). Whereas mangroves in Kuwait are rare, and areas like Bahrain, Qatar and Saudi Arabia remained stable with a slight increase. Mangroves in Iran suffered a decline throughout the years (Almahasheer, 2018; Almahasheer *et al.*, 2013), however, recent estimates of the extent of mangroves could indicate potential increases (Naderloo, *et al.*, 2023), but additional spatial distribution datasets are required to further verify the extent. As of 2020, the estimated extent of mangroves in this province was 209.5 km^2, representing about 0.1 % of the global mangrove area, with net area change of -14.3 % from 1996 to 2020 (Bunting *et al*., 2022). However, these estimates vary due to the use of various methodologies and imagery.

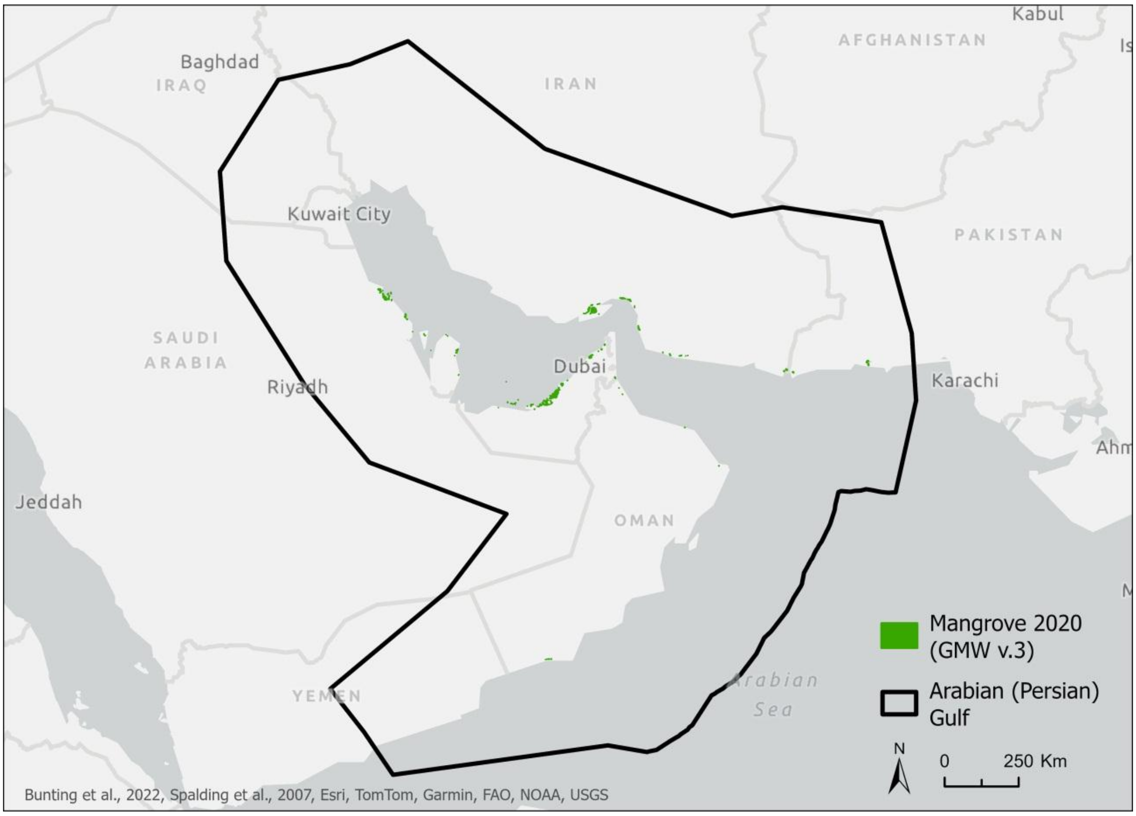


Figure 1. Map of mangroves distribution along the Arabian (Persian) Gulf and Arabian Sea. Due to insufficient spatial data, the map does not depict a small mangrove area in Yemen's Al Maharah Governorate, referenced in literature (see Nagi *et al.*, 2012)

Biotic components of the ecosystem (characteristic native biota)

The mangroves of the Arabian (Persian) Gulf province are low in diversity with four recorded true mangrove plant species; *Rhizophora mucronata*, *Avicennia marina*, *Aegiceras corniculatum*, and *Ceriops tagal* (IUCN, 2022). Historically, two dominant species; *Rhizophora mucronata* and *Avicennia marina*, colonised the Arabian (Persian) Gulf (Sheppard *et al*., 1992). However, *R. mucronata* became extinct from the southern part of the Arabian (Persian) Gulf (Hellyer and Aspinall, 2005). Presently both species are only found along the northern Arabian (Persian) Gulf of Iran’s coastline and the Balochistan coast of Pakistan, while only one species; *Avicennia marina*, occurs naturally along the rest of the Arabian (Persian) Gulf (Almahasheer, 2018).

The limited diversity of mangrove species is due to this province’s extremely arid climate, resulting in high salinity conditions unfavourable to less tolerant mangrove species (Hellyer and Aspinall, 2005). The harsh environment of the Arabian (Persian) Gulf also stresses mangroves, which restricts their growth rate to as little as 0.1 cm / month (Saenger *et al*., 2004), while mangrove stands appear stunted, dwarf-like, and sparse, and are frequently intermingled with non-mangrove, salt-tolerant shrub species (e.g., *Arthrocnemum macrostachyum* and *Halocnemum strobilaceum*) (Hellyer and Aspinall, 2005).

According to the IUCN Red List of Threatened Species (IUCN, 2022), there are at least 180 species within the taxa Actinopterygii, Aves, Mammalia, Reptilia, and Chondrichthyes associated directly or indirectly with mangrove habitats, where at least twenty are found within Arabian (Persian) Gulf region. The direct species associated with mangroves of this province are *Calidris ferruginea* (Curlew Sandpiper) listed as Near Threatened; *Epinephelus coioides* (Orange-spotted Grouper) listed as Vulnerable, and *Negaprion acutidens* (Sharptooth Lemon Shark) listed as Endangered (IUCN, 2022) (See Annex). The common fauna associated with mangroves includes many fish species, crabs, prawns, and molluscs (Hellyer and Aspinall, 2005).

Abiotic Components of the Ecosystem

Regional mangrove distributions are influenced by interactions among landscape position, temperature and rainfall, hydrology, sea-level, sediment dynamics, soil characteristics, storm-driven processes, and disturbance by pests and predators. Mangroves of the Arabian (Persian) Gulf occupy sheltered intertidal lagoons along coastlines and offshore islands containing various soil types including highly organic soft sediments, clay or sandy soils low in organic matter, and consolidated hard substrata (Hellyer and Aspinall, 2005). The Arabian (Persian) Gulf interior is characterized by limited freshwater input (less than 90 mm precipitation annually), large fluctuating sea-water temperatures (ranging from 12°C in winter to 35°C in summer), unusual north winds, and high evaporation rates that cause high salinity (average salinity 42 ppt) (Sheppard *et al*., 1992). The Balochistan coast of Pakistan is also water-deficient, with average annual precipitation of only 130 mm (FAO, 2007). Prolonged high temperatures in summer months, coupled with high evaporation rates can decrease oxygen levels and greatly increase salinity levels in mangrove soils. Only the most salt-tolerant mangrove species, *Avicennia marina*, is able to withstand salinities in the Arabian (Persian) Gulf that can range from 48 to 70 ppt in some lagoons (Sheppard *et al*., 1992, 2010).

Key processes and interactions

Mangroves of the Arabian (Persian) Gulf provide important ecosystem services across the marine environment for supporting biodiversity and local communities. They act as structural engineers possessing traits such as pneumatophores, salt excretion glands, vivipary, and propagule buoyancy that promote survival and recruitment in poorly aerated, saline, mobile, and tidally inundated soils. The key processes undertaken within mangrove soils, and the availability of oxygen, are major contributors to the provision of various services (Figure 2). The soil quality and its composition promote the development of mangrove trees. The duration of tidal inundation, availability of freshwater (e.g., from precipitation), and the levels of oxygen are also major processes within mangroves ecosystems. Tidal inundation typically occurs twice daily and ranges from 0.2 meters to three meters. This process regulates soil composition significantly by delivering an influx of new nutrients, while also regulating the level of oxygen. While the growth of *A. marina* was not previously assessed using internodal analysis in the Western Arabian (Persian) Gulf, the node production in 40 branches/axillary shoot in Syhat city, Saudi Arabia, ranged from 6 to 9 nodes y^{-1}, with a branch growth rate from 15 to 46.5 cm; median of 25.5 cm per year (Almahasheer, 2021).

The process of inundation is also critical for the interaction between mangroves and oxygen uptake. During the high tide, mangrove pneumatophores are submerged, thus, respiration cannot occur, whilst during low tide respiration continues due to exposure to air. The hyper-arid climate of the Arabian (Persian) Gulf causes extreme evaporation rates that also affect salinity in the ecosystem. The salinity levels recorded across mangroves of the Arabian (Persian) Gulf range between 40 and 50 ppt, however, prolonged high salinity levels above this range may cause signs of stress on trees, followed by health deterioration. Hence, tidal inundation is vital for regulating salinity levels. The unusual dynamics of the northern winds also cause sudden severe waves across the intertidal areas which can be considered as another key process of interaction in mangrove ecosystems of the Arabian (Persian) Gulf. These processes may have an impact on new recruitments and growth development of saplings due to the instability of the marine environment, affecting dispersal and anchoring of propagules.

Mangroves also produce large amounts of detritus (e.g., leaves, twigs, and bark), which is either buried in waterlogged sediments, or consumed by crabs and other invertebrates, thus, mobilising carbon, and nutrients to other trophic levels. Mangroves play a vital role along the coastline of this ecoregion by supporting primary production for a variety of fish (e.g., *Gerres longirostris* and *Lutjanus argentimaculatus*), birds (e.g., *Ardea cinerea*), crabs (e.g., *Metopograpsus messor*), and marine invertebrates (such as Crustaceans and Molluscs). Burrowing by crabs and marine invertebrates within mangrove soils is a key process for improving soil quality and composition, which supplements regular levels of oxygen and salinity in mangrove ecosystems. The specialised mangrove roots (pneumatophores) offer shelter and protection for many juvenile fish and shrimp species, while the tree canopy cover provides the significant service of shade from prolonged ultraviolet radiation emitted by the sun and cooler sea-water temperatures.

Mangrove ecosystems also serve as major blue carbon sinks, incorporating organic matter into sediments and living biomass. Mangroves soil carbon sequestration of the Southern Arabian (Persian) Gulf range from 8.63 g C_{org} m^{-2} yr^{-1} to 111.38 g C_{org} m^{-2} yr^{-1} with a mean of 57.67 ± 2.90 g C_{org} m^{-2} yr^{-1} (Crooks, *et al*., 2021). These rates are higher than reported rates from this arid region, for example the reported rates for Red Sea mangroves are 15 ± 1 g C_{org} m^{-2} yr^{-1} (Almahasheer *et al*., 2017), and 19 ± 11 g C_{org} m^{-2} yr^{-1} for the western Arabian (Persian) Gulf (Cusak *et al*., 2018). However, the rates reported from the Arabian (Persian) Gulf are much lower than global mean sequestration rates of 170 g C_{org} m^{-2} yr^{-1} (Perez *et al*., 2018). Moreover, mangrove forests of the Arabian (Persian) Gulf seem to keep pace with the high contemporary sea-level rise (SLR), resulting from the combined effects of global anthropogenic climate change and regional land subsidence (Saderne *et al*., 2018). The N and P stocks (in 0.2 m thick-sediments) and accumulation rates (for the last century based on ^{210}Pb and for the last millennia based on ^{14}C) in mangrove, seagrass, and saltmarsh sediments from eight locations along the coast of Saudi Arabia (81 cores in total). Finally, the major contributing factors of mangroves health degradation and loss are direct tree removal, coastal infrastructure activities, particularly the impacts of dredging (e.g., deepening and widening of channels) and landfilling near mangrove soils, which causes high levels of eutrophication and modification of substrates.

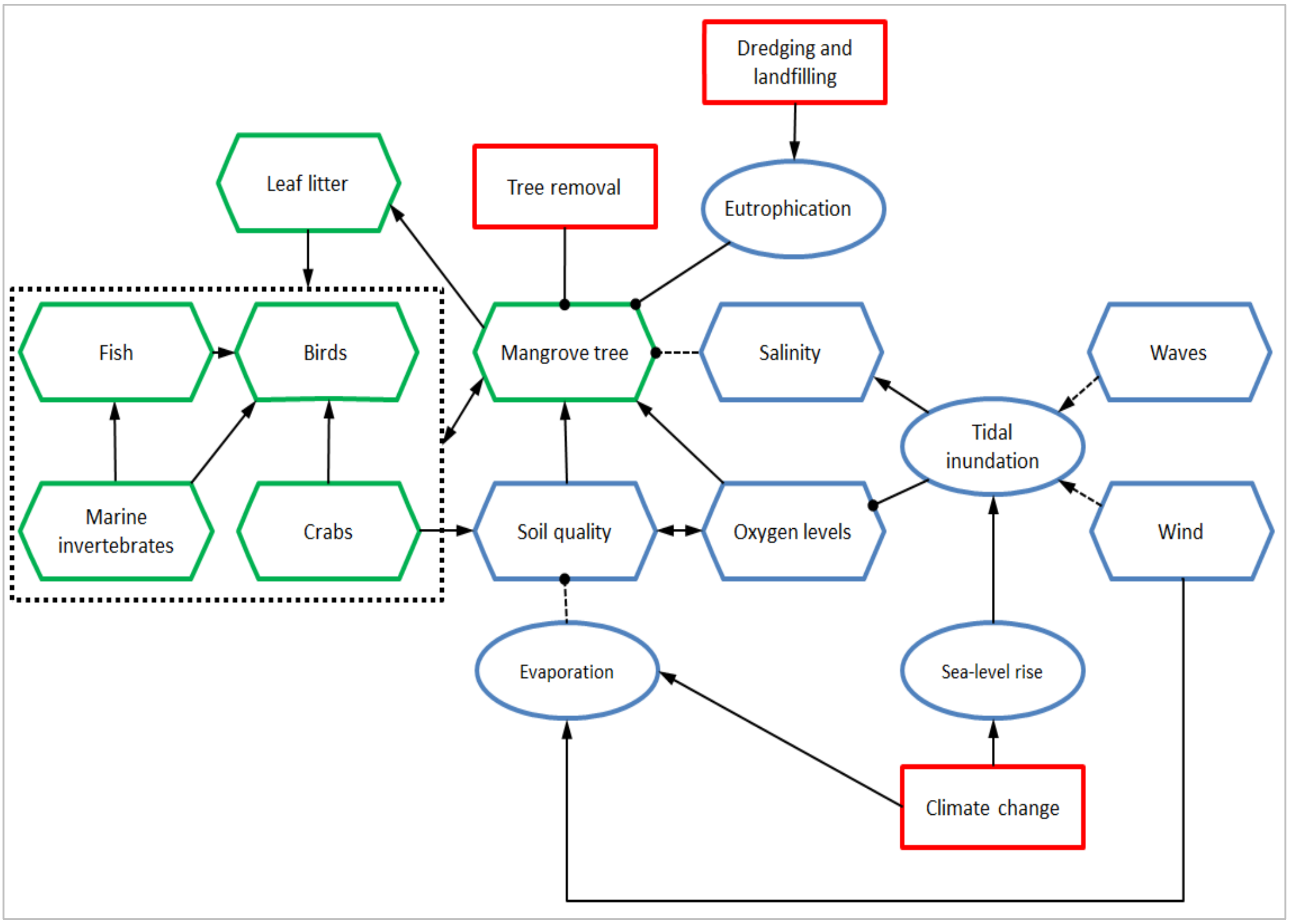


Figure 2. Conceptual model of key processes of abiotic and biotic components and threats relevant to the risk assessment for mangrove forests of Arabian (Persian) Gulf. Hexagons represent key components (biotic in green and abiotic in blue); ellipses represent key processes (biotic in green and abiotic in blue); and red boxes represent threats. Pointed arrows indicate positive effects; rounded arrows indicate negative effects, while dashed line indicates either potential positive or negative effects.

3. Ecosystem Threats and vulnerabilities

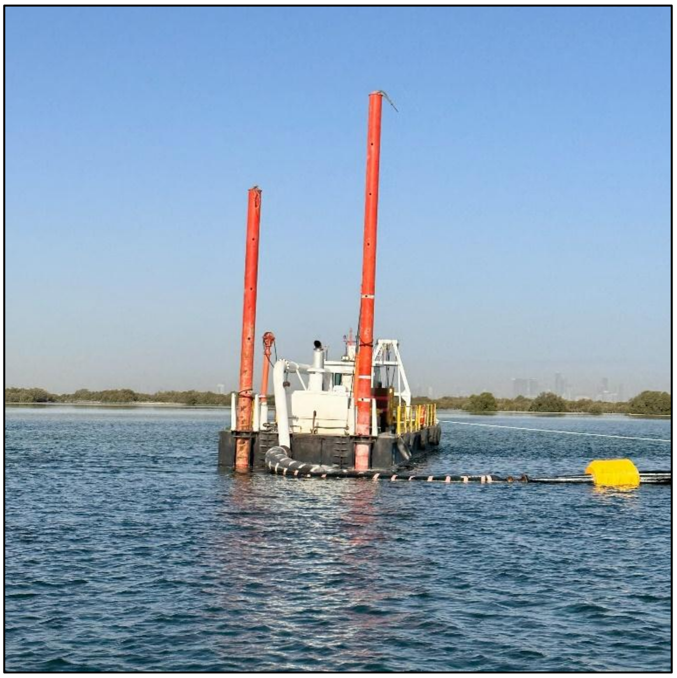
Main threatening process and pathways to degradation

Mangrove degradation arises from various factors, including aquaculture, urbanization, associated coastal development, over-harvesting, and pollution stemming from domestic, industrial, and agricultural land use. Fishing activities and resource use by small-scale fishers and local communities are minor in the region, thus, they are not considered as major threats to ecosystem collapse.

Small-scale fishing in a mangrove-fringed lagoon in Balochistan Province, Pakistan
(Photo credit: Don Macintosh)

Throughout the Arabian (Persian) Gulf the most pressing threats to mangroves are anthropogenic disturbances mainly from coastal dredging to widen or deepen channels near or within mangrove areas; and landfilling from benthic sedimentation removal for coastal infrastructure and man-made islands (Hellyer and Aspinall, 2005). The alteration of hydrodynamics and the water flow (e.g., daily tidal inundation) by natural or anthropogenic modifications across intertidal zones of the Arabian (Persian) Gulf mangroves will heavily disrupt the ecosystem, particularly if the threat is frequent and prolonged. As a result, extreme salinity greater than 70 ppt with depleted oxygen levels in mangrove soils may adversely affect ecosystem functioning. Increased levels of freshwater input could support the ecosystem (Saenger *et al*., 2004). Disruption of soil composition and soil quality will negatively affect associated population of marine fauna and invertebrates and disrupt primary production and tropic levels. The degraded health of mangroves and loss will reduce services such as water quality and sedimentation trapping, indirectly affecting adjacent ecosystems such as saltmarsh communities, mudflats, and seagrass meadows (Hogarth, 2015).

Other human-induced threats to the ecosystem include pollution, especially oil spills that could smear oil on to pneumatophores and mangrove soils (Hellyer and Aspinall, 2005; FAO, 2007). A recent estimate revealed that about 82% of the Arabian (Persian) Gulf Western coasts are non-polluted to slightly polluted (Amin and Almahasheer, 2022). Large plastic objects are more frequent in mangroves than on beaches, because they are sinks for marine litter and traps for land litter as well, with a total of 450 litter items recorded in the Arabian (Persian) Gulf, yielding an average of 1.21 ± 0.53 items m^{-2} across transects. Litter densities were recorded ranging from 0.22 ± 0.06 items m^{-2} in Safwa to 3.0 ± 2.0 items m^{-2} on Tarout island (Martin *et al*., 2019). Desalination plants are another cause of concern, the increased salinity levels, if reached above threshold (> 70), could cause severe stress possibly mangroves loss and degrade nearby ecosystems and associated fauna (Saenger *et al*., 2004). Natural threats to mangroves by northern strong winds causing high waves and storms can damage mangrove forests through direct defoliation and destruction of trees, as well as through the mass mortality of animal communities within the ecosystem. Growth of grasses on open mudflats, colonisation of the back mangrove zone by the invasive mesquite shrub (*Prosopis juliflora*), or smothering by sand from shifting sand dunes, can also impede mangrove growth and development in Pakistan. Additionally, predicted sea-level rise as a result of climate change, may affect growth in the long term if they do not keep pace of sea-level rise, due to the Arabian (Persian) Gulf's low-lying coastal topography (Saenger *et al*., 2004).



Dredging activities near mangroves of Southern Arabian (Persian) Gulf, United Arab Emirates (Photo credit: Amna Almansoori).

Marine landfill near mangroves of Southern Arabian (Persian) Gulf, United Arab Emirates (Photo credit: Amna Almansoori).

Erosion by anthropogenic activities near mangroves of the Southern Arabian (Persian) Gulf, United Arab Emirates (Photo credit: Amna Almansoori).

Threats of littering to mangroves near Eastern Arabian (Persian) Gulf, Saudi Arabia (Photo credit: Hanan Almahasheer).

Definition of the collapsed state of the ecosystem

Mangroves are dynamic ecosystems that tolerate high salinity, wave action and daily tidal inundation rarely experienced by terrestrial or freshwater plants. They possess specialized traits that facilitate high nitrogen use efficiency and nutrient resorption, thereby influencing critical ecosystem processes and functions. Ecosystem collapse is recognized when the tree cover of diagnostic true mangrove species dwindles to zero, indicating complete loss (100%). 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. Ecosystem collapse may manifest through the following mechanisms: a) restricted recruitment and survival of diagnostic true mangroves due to adverse climatic conditions (e.g., prolonged sea-water temperature above 35°C), or human-induced land modifications (e.g., marine route channels or landfills); b) alterations in freshwater input (e.g., less than annual average precipitation of 90 mm), waves or tidal currents that destabilize and erode soft sediments, hindering recruitment and growth; c) shifts in salinity patterns (threshold > 70 ppt) and tidal inundation levels (threshold > two meters); and (d) land use and modification due to coastal infrastructure (e.g., urbanization, dredging, construction of bridges, landfill), groundwater extraction (for domestic or commercial use), industrial runoff (e.g., from desalination plants) or marine pollution; hence, altering salinity levels and nutrient loadings, thereby affecting mangrove soil quality and composition and impacting mangrove survival. The loss of mangrove habitats in the Arabian (Persian) Gulf could lead to ecosystem collapse, affecting nearby ecosystems (e.g., seagrass meadows) and result in an overall reduction of biodiversity and fisheries production.

Threat Classification

IUCN Threat Classification (version 3.3, IUCN-CMP 2022) relevant to mangroves of the Arabian (Persian) Gulf province:

1. Residential & Commercial Development
- 1.2 Housing & Urban Areas
- 1.2 Commercial & Industrial Areas
- 1.3 Tourism & Recreation Areas

3. Energy Production & Mining
- 3.1 Oil & Gas Drilling

4. Transportation & Service Corridors
- 4.1 Roads & Railroads
- 4.2 Utility & Service Lines
- 4.3 Shipping Lanes

5. Biological Resource Use
- 5.4 Fishing & Harvesting Aquatic Resources
  - 5.4.3 Unintentional Effects: Subsistence/Small Scale

7. Natural System Modifications
- 7.2 Dams & Water Management/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)

7.3 Other Ecosystem Modifications

9. Pollution

9.1 Domestic & Urban Waste Water

9.1.2 Run-Off

9.2 Industrial & Military Effluents

9.2.1 Oil Spills

9.3 Agricultural & Forestry Effluents

9.3.1 Nutrient Loads

9.3.2 Soil Erosion, Sedimentation

11. Climate Change & Severe Weather

11.1 Habitat Shifting & Alteration

11.2 Droughts

11.3 Temperature Extremes

11.4 Storms & Flooding

11.5 Other Impacts (sea-level rise)

4. Ecosystem Assessment

Criterion A: Reduction in Geographic Distribution

Subcriterion A1 measures the trend in ecosystem extent during the last 50-year time window. Unfortunately, there is currently no common regional dataset that provides information for the entire target area in 1970. However, country-level estimates of mangrove extent can be used to extrapolate the trend between 1970 and 2020. Accordingly, we compiled reliable published sources (see appendix 3) that contain information on mangrove area estimates close to 1970 (both before and after) for each country within the province. These estimates were then used to interpolate the mangrove area in 1970 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 3 for further details of the methods and limitations).

Two primary sources were used to estimate the mangrove area in 1970: FAO’s (2007) report on the global status and trends of mangroves and the spatial analysis by Milani (2018) (Annex 3 - Table b). Significant differences between the sources resulted in both low and high estimates (Annex 3 - Table a). Iran’s mangrove area, which is the largest mangrove area in the province, was estimated at 39.5 km^2 based on Milani (2018) versus 303 km^2 using FAO’s (2007) trends. Consequently, the total mangrove area in the Arabian (Persian) Gulf in 1970 was estimated to be between 101.52 and 442.94 km^2. The lower estimate was based on Milani (2018) time series while the higher estimate was obtained based on FAO (2007).

In addition, the latest version of the Global Mangrove Watch (GMW v3.0) spatial dataset was used to estimate the mangrove area in the Arabian (Persian) Gulf from 1996 to 2020. Mangrove area in the province (and corresponding countries) was corrected for errors of omission and commission, using the equations in Bunting *et al.*, (2022).

The analysis revealed a net reduction in mangrove coverage (-14.3%), mainly in Bahrain, Qatar, Pakistan, Oman, and Iran. Notably, Iran’s mangroves, contributing to the largest portion in the province at 53%, experienced a negative net change of ~31 km^2 (Bunting *et al.*, 2022). However, other studies reported a net increase over the same period ranging from 8.4 km^2 and 14 km^2 (Milani 2018, Erfanifard *et al.*, 2022). Estimates of Iran's mangrove area in 2020 also varied significantly (Naderloo *et al.* 2023, Erfanifard *et al.* 2022, Milani 2018, Almahasheer *et al.* 2017) (see Annex 3). Mangroves in the United Arab Emirates, the second largest mangrove extent in the province at 35.6%, exhibited slight changes according to the GMW dataset (-2%). Other sources reported an overall increase of 50.69 km^2 from the years 2001-2017 (Helena *et al.*, 2020).

Results from the analysis of subcriterion A1 (Annex 3) reveal a notable change in the Arabian (Persian) Gulf mangroves over the past 50 years (1970-2020). These changes indicate a fluctuation ranging between a decrease of -52.7 % and an increase of +106.4% of its mangrove area. This variability places the Arabian (Persian) Gulf mangrove province between the Least Concern (LC) and Endangered (EN) threat categories. Consequently, the ecosystem is assessed as **Vulnerable** under Subcriterion A1, with a plausible range between Least Concern and Endangered (LC-EN).

	Area 2020* (Km^2)		**Area 1970* (Km^2)**	**Net area Change (Km^2)**	**% Net Area Change**	**Rate of change (%/year)**
Mangroves of the Arabian (Persian) Gulf	209.5	**Lower Estimate**	101.5	108	106.4%	2.1%
		Higher Estimate	442.9	-233.4	-52.7%	-1.1%

** Details on the methods and references used to estimate the mangrove area in 1970 are listed in appendix 3. Total mangrove area in 2020 is based on the Global Mangrove Watch Version 3 (GMW v3.0) dataset.*

Subcriterion A2 measures the change in ecosystem extent in any 50-year period, including from the present to the future: The Arabian (Persian) Gulf province mangroves show a net area change of -14.3% (1996-2020) based on the Global Mangrove Watch time series (Bunting *et al.*, 2022). This value reflects the offset between areas gained (+ 0.2%/year) and lost (- 0.8%/year). The largest decrease in mangrove area in this time series occurred between 2007 and 2020. Applying a linear regression to the area estimations between 1996 and 2020 we obtained a rate of change of -0.6%/year (Figure 3). Assuming this trend continues in the future, it is predicted that the extent of mangroves in the Arabian (Persian) Gulf province will change by -34.2% from 1996 to 2046; by -52.8% from 1996 to 2070; but by -45.0% from 2020 to 2070. Given that these predicted changes in mangrove extent are above 30% but below the 50% risk threshold, the Arabian (Persian) Gulf mangrove ecosystem is assessed as **Vulnerable (VU)** under subcriterion A2.

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

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

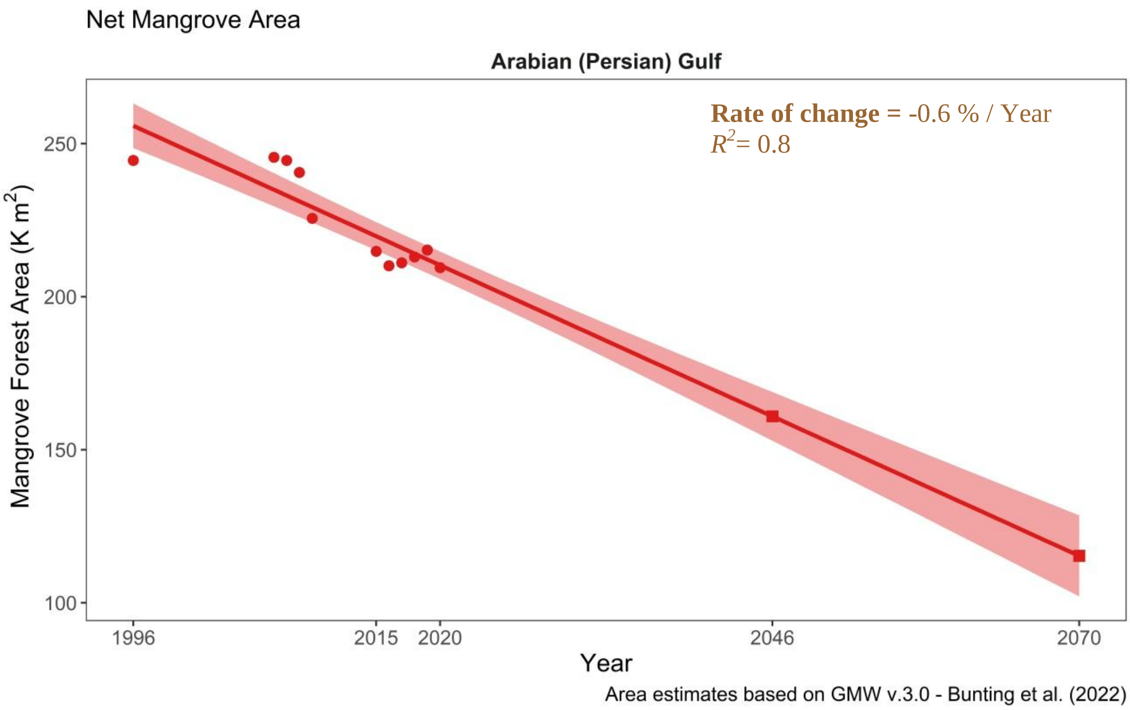


Figure 3. Projected extent of the Arabian (Persian) Gulf mangrove ecosystem to 2070. Circles represent the province mangrove area between 1996 and 2020 based on the GMW v3.0 dataset and equations in Bunting *et al*., (2022). The solid line and shaded area are the linear regression and 95% confidence intervals. Squares show the Arabian (Persian) Gulf 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 (R2 = 0.8).

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 Arabian (Persian) Gulf province mangrove extent (GMW v.3).

Province	Extent of Occurrence EOO (Km^2)	Area of Occupancy (AOO) ≥ 1%	Criterion B
The Arabian (Persian) Gulf	896429.0	51	**LC**

For 2020, AOO and EOO were measured as 141 grid cells 10 x 10 km and 896,429.0 km^2, respectively (Figure 4). Excluding from the AOO those grid cells that contain patches of mangrove forest that account for less than 1% of the grid cell area, (< 1 km^2), the AOO is measured as **51, 10 x 10 km grid cells** (Figure 4, red grids). The Southern Arabian (Persian) Gulf (United Arab Emirates) mangroves are under AOO >= 1 %, however, more than 10 threats-defined locations are present due to mangroves distribution less than 5 km^2

from urban development and coastal infrastructure. Though these threats will not collapse the ecosystem in one event, but will take more than three consecutive events, rendering their future position as vulnerable areas (Almansoori *et al.*, 2021). However, considering the very high number of threat-defined-locations, there is no evidence of plausible catastrophic threats leading to potential disappearance of mangroves across their extent. As a result, the Arabian (Persian) Gulf mangrove ecosystem is assessed as **Least Concern (LC)** under criterion B.

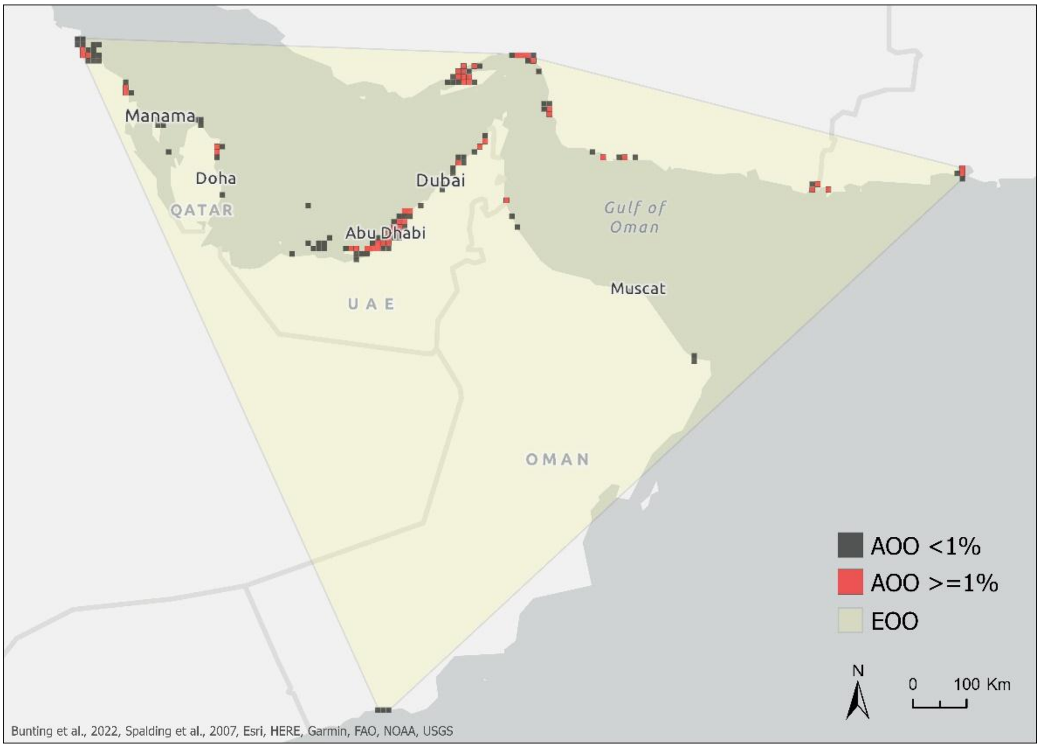


Figure 4. The Arabian (Persian) Gulf mangrove Extent of Occurrence (EOO) and Area Of Occupancy (AOO) in 2020. Estimates based on 2020 GMW v3.0 spatial layer (Bunting *et al.*, 2022). The red 10 x 10 km grids (n=51) are more than 1% covered by the ecosystem, and the black grids <1% (n= 90).

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. Assessment of salinity data for years between 2011 and 2020 across the Southern Arabian (Persian) Gulf show highest value of 49.3 in 2014 indicating below the collapse threshold indicated for the ecosystem, however, this data was not sufficient to measure environmental degradation (Almansoori *et al.*, 2021). Therefore, there are no reliable data to evaluate this subcriterion for the entire province, and therefore the Arabian (Persian) Gulf 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 Arabian (Persian) Gulf mangrove ecosystem boundary, with spatial extent based on (Giri *et al.*, 2011) and assuming mangrove landward migration was not possible.

According to the results, under an extreme SLR scenario of a 1.1-meter rise by 2100, the projected submerged area is ~ -16.1 % 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 -16.1 % of the ecosystem extent will be affected by SLR, the Arabian (Persian) Gulf 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 Arabian (Persian) Gulf province is classified as Data Deficient (DD) for this subcriterion.

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

Criterion D: Disruption of biotic processes or interactions

The global mangrove degradation map developed by Worthington and Spalding (2018) was used to assess the level of biotic degradation in the Arabian (Persian) Gulf 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: https://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), 1.4 % of the Arabian Gulf mangrove area is classified as degraded, resulting in an average annual rate of degradation of 0.01 %. Assuming this trend remains constant, + 3.34 % of the Arabian (Persian) Gulf mangrove area will be classified as degraded over a 50-year period. Since less 30 % of the ecosystem will meet the category thresholds for criterion D, the Arabian (Persian) Gulf 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 Arabian (Persian) Gulf ecosystem remains **Least Concern (LC)** under criterion D.

Criterion E: Quantitative Risk

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

5. Summary of the Assessment

CRITERION			
A. Reduction in Geographic Distribution	**A1** Past 50 years	**A2** Future or any 50y period	**A3** Historical (1750)
	VU	VU	DD
B. Restricted Geo. Distribution	**B1** Extent of Occurrence	**B2** Area of Occupancy	**B3** Threat-defined Locations < 5?
	LC	LC	LC
C. Environmental Degradation	**C1** Past 50 years (1970)	**C2** Future or any 50y period	**C3** Historical (1750)
	DD	LC	DD
D. Disruption of biotic processes	**D1** Past 50 years (1970)	**D2** Future or Any 50y period	**D3** Historical (1750)
	DD	LC	DD
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	VU		

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

Overall, the status of the Arabian (Persian) Gulf mangrove ecosystem is assessed as **Vulnerable (VU).**

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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	Lamiales	Acanthaceae	*Avicennia marina*	LC
Magnoliopsida	Rhizophorales	Rhizophoraceae	*Rhizophora mucronata*	LC
Magnoliopsida	Ericales	Primulaceae	*Aegiceras corniculatum*	LC
Magnoliopsida	Malpighiales	Rhizophoraceae	*Ceriops tagal*	LC

2. List of Associated Species

List of taxa that are associated with mangrove habitats in the Red List of Threatened Species (RLTS) database (IUCN, 2022). We included only species with entries for Habitat 1.7: “Forest - Subtropical/Tropical Mangrove Vegetation Above High Tide Level” or Habitat 12.7 for “Marine Intertidal - Mangrove Submerged Roots”, and with suitability recorded as “Suitable”, with “Major Importance” recorded as “Yes”, with Presence recorded as “Extant”, “Possibly Extant” or “Possibly Extinct”, Origin recorded as "Native" or "Reintroduced" and with any value of Seasonality except “Passage. The common names are those shown in the RLTS.

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Charadriiformes	Scolopacidae	*Calidris ferruginea*	NT	Curlew sandpiper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus coioides*	VU	Orange-spotted Grouper
Magnoliopsida	Malvales	Malvaceae	*Thespesia populnea*	LC	Portia tree
Actinopterygii	Perciformes	Sparidae	*Acanthopagrus berda*	LC	Picnic seabream
Actinopterygii	Perciformes	Sparidae	*Acanthopagrus bifasciatus*	LC	Two-bar Seabream
Aves	Accipitriformes	Accipitridae	*Accipiter tachiro*	LC	African goshawk
Aves	Passeriformes	Sturnidae	*Acridotheres tristis*	LC	Common myna
Aves	Charadriiformes	Scolopacidae	*Actitis hypoleucos*	LC	Common sandpiper
Actinopterygii	Albuliformes	Albulidae	*Albula glossodonta*	VU	Shortjaw bonefish
Aves	Coraciiformes	Alcedinidae	*Alcedo atthis*	LC	Common kingfisher
Aves	Gruiformes	Rallidae	*Amaurornis phoenicurus*	LC	White-breasted Waterhen
Aves	Suliformes	Anhingidae	*Anhinga rufa*	LC	African darter
Chondrichthyes	Rhinopristiformes	Pristidae	*Anoxypristis cuspidata*	EN	Narrow sawfish
Aves	Passeriformes	Cisticolidae	*Apalis flavocincta*	LC	Brown-tailed Apalis
Aves	Caprimulgiformes	Apodidae	*Apus affinis*	LC	Little swift
Aves	Caprimulgiformes	Apodidae	*Apus caffer*	LC	White-rumped Swift
Aves	Pelecaniformes	Ardeidae	*Ardea brachyrhyncha*	LC	Yellow-billed Egret
Aves	Pelecaniformes	Ardeidae	*Ardea cinerea*	LC	Grey heron

Class	Order	Family	Scientific name	RLTS category	Common name
Aves	Pelecaniformes	Ardeidae	*Ardea goliath*	LC	Goliath heron
Aves	Pelecaniformes	Ardeidae	*Ardea intermedia*	LC	Intermediate egret
Aves	Pelecaniformes	Ardeidae	*Ardea purpurea*	LC	Purple heron
Aves	Pelecaniformes	Ardeidae	*Ardeola grayii*	LC	Indian Pond-heron
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron hispidus*	LC	White-spotted Puffer
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron immaculatus*	LC	Immaculate puffer
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Arothron stellatus*	LC	Stellate puffer
Actinopterygii	Gobiiformes	Gobiidae	*Asterropteryx semipunctata*	LC	Star-finned Goby
Actinopterygii	Atheriniformes	Atherinidae	*Atherinomorus lacunosus*	LC	Hardyhead silverside
Actinopterygii	Perciformes	Carangidae	*Atule mate*	LC	Yellowtail scad
Reptilia	Squamata	Viperidae	*Bitis arietans*	LC	Puff adder
Aves	Pelecaniformes	Threskiornithidae	*Bostrychia hagedash*	LC	Hadada ibis
Magnoliopsida	Malpighiales	Rhizophoraceae	*Bruguiera gymnorhiza*	LC	Oriental mangrove
Aves	Charadriiformes	Burhinidae	*Burhinus vermiculatus*	LC	Water Thick-knee
Actinopterygii	Gobiiformes	Eleotridae	*Butis butis*	LC	Crimson-tipped Gudgeon
Aves	Pelecaniformes	Ardeidae	*Butorides striata*	LC	Green-backed Heron
Aves	Passeriformes	Cisticolidae	*Camaroptera brachyura*	LC	Bleating camaroptera
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus amblyrhynchoides*	VU	Graceful shark
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus amboinensis*	VU	Pigeye shark
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Carcharhinus melanopterus*	VU	Blacktip reef shark
Aves	Passeriformes	Hirundinidae	*Cecropis abyssinica*	LC	Lesser striped swallow
Insecta	Odonata	Coenagrionidae	*Ceriagrion cerinorubellum*	LC	Na
Gastropoda	Sorbeoconcha	Potamididae	*Cerithidea decollata*	LC	Na
Aves	Coraciiformes	Alcedinidae	*Ceryle rudis*	LC	Pied kingfisher
Aves	Charadriiformes	Charadriidae	*Charadrius dubius*	LC	Little ringed plover
Aves	Charadriiformes	Charadriidae	*Charadrius mongolus*	LC	Lesser sandplover
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Chelonodontops patoca*	LC	Milkspotted puffer
Chondrichthyes	Orectolobiformes	Hemiscylliidae	*Chiloscyllium arabicum*	NT	Arabian carpetshark
Mammalia	Primates	Cercopithecidae	*Chlorocebus pygerythrus*	LC	Vervet monkey
Aves	Ciconiiformes	Ciconiidae	*Ciconia microscelis*	LC	African woollyneck
Aves	Passeriformes	Nectariniidae	*Cinnyris venustus*	LC	Variable sunbird
Aves	Accipitriformes	Accipitridae	*Clanga clanga*	VU	Greater spotted eagle
Gastropoda	Neogastropoda	Conidae	*Conus varius*	LC	Na
Aves	Coraciiformes	Alcedinidae	*Corythornis cristatus*	LC	Malachite kingfisher
Reptilia	Crocodylia	Crocodylidae	*Crocodylus niloticus*	LC	Nile crocodile
Reptilia	Squamata	Colubridae	*Crotaphopeltis hotamboeia*	LC	Red-lipped Snake

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Pleuronectiformes	Cynoglossidae	*Cynoglossus puncticeps*	LC	Speckled tonguesole
Aves	Piciformes	Picidae	*Dendropicos fuscescens*	LC	Cardinal woodpecker
Aves	Passeriformes	Malaconotidae	*Dryoscopus cubla*	LC	Black-backed Puffback
Mammalia	Sirenia	Dugongidae	*Dugong dugon*	VU	Dugong
Reptilia	Squamata	Viperidae	*Echis carinatus*	LC	Saw-scaled Viper
Aves	Pelecaniformes	Ardeidae	*Egretta ardesiaca*	LC	Black heron
Aves	Pelecaniformes	Ardeidae	*Egretta garzetta*	LC	Little egret
Aves	Pelecaniformes	Ardeidae	*Egretta gularis*	LC	Western Reef-egret
Actinopterygii	Elopiformes	Elopidae	*Elops machnata*	LC	Na
Actinopterygii	Ophidiiformes	Carapidae	*Encheliophis homei*	LC	Silver pearlfish
Liliopsida	Alismatales	Hydrocharitaceae	*Enhalus acoroides*	LC	Species code: Ea
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus coeruleopunctatus*	LC	Whitespotted grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus malabaricus*	LC	Malabar grouper
Actinopterygii	Perciformes	Epinephelidae	*Epinephelus tauvina*	DD	Greasy grouper
Reptilia	Testudines	Cheloniidae	*Eretmochelys imbricata*	CR	Hawksbill turtle
Aves	Coraciiformes	Coraciidae	*Eurystomus glaucurus*	LC	Broad-billed Roller
Actinopterygii	Perciformes	Leiognathidae	*Gazza minuta*	LC	Toothed ponyfish
Actinopterygii	Perciformes	Gerreidae	*Gerres filamentosus*	LC	Whipfin mojarra
Aves	Coraciiformes	Alcedinidae	*Halcyon senegaloides*	LC	Mangrove kingfisher
Aves	Coraciiformes	Alcedinidae	*Halcyon smyrnensis*	LC	White-breasted Kingfisher
Aves	Accipitriformes	Accipitridae	*Haliaeetus vocifer*	LC	African Fish-eagle
Aves	Accipitriformes	Accipitridae	*Haliastur indus*	LC	Brahminy kite
Liliopsida	Alismatales	Cymodoceaceae	*Halodule uninervis*	LC	Species code: Hu
Liliopsida	Alismatales	Cymodoceaceae	*Halodule wrightii*	LC	Species code: Hw
Liliopsida	Alismatales	Hydrocharitaceae	*Halophila ovalis*	LC	Species code: Ho
Reptilia	Squamata	Gekkonidae	*Hemidactylus robustus*	LC	Red Sea Leaf-toed Gecko
Chondrichthyes	Myliobatiformes	Dasyatidae	*Himantura uarnak*	EN	Coach whipray
Actinopterygii	Syngnathiformes	Syngnathidae	*Hippichthys cyanospilos*	LC	Bluespeckled pipefish
Actinopterygii	Syngnathiformes	Syngnathidae	*Hippichthys penicillus*	LC	Beady pipefish
Aves	Passeriformes	Acrocephalidae	*Hippolais languida*	LC	Upcher's warbler
Holothuroidea	Aspidochirotida	Holothuriidae	*Holothuria impatiens*	DD	Bottleneck sea cucumber
Holothuroidea	Aspidochirotida	Holothuriidae	*Holothuria parva*	DD	Na
Holothuroidea	Aspidochirotida	Holothuriidae	*Holothuria scabra*	EN	Golden sandfish
Reptilia	Squamata	Elapidae	*Hydrophis cyanocinctus*	LC	Annulated sea snake
Reptilia	Squamata	Elapidae	*Hydrophis gracilis*	LC	Graceful Small-headed Seasnake
Reptilia	Squamata	Elapidae	*Hydrophis schistosus*	LC	Beaked sea snake

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Gobiiformes	Gobiidae	*Istigobius ornatus*	LC	Ornate goby
Aves	Pelecaniformes	Ardeidae	*Ixobrychus minutus*	LC	Common little bittern
Aves	Pelecaniformes	Ardeidae	*Ixobrychus sinensis*	LC	Yellow bittern
Aves	Pelecaniformes	Ardeidae	*Ixobrychus sturmii*	LC	Dwarf bittern
Actinopterygii	Perciformes	Sciaenidae	*Johnius belangerii*	LC	Belanger's croaker
Actinopterygii	Perciformes	Sciaenidae	*Johnius borneensis*	LC	Hammer croaker
Actinopterygii	Perciformes	Sciaenidae	*Johnius carouna*	LC	Caroun croaker
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Lagocephalus guentheri*	LC	Diamondback puffer
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Lagocephalus lunaris*	LC	Lunartail puffer
Aves	Charadriiformes	Laridae	*Larus hemprichii*	LC	Sooty gull
Actinopterygii	Perciformes	Leiognathidae	*Leiognathus equulus*	LC	Common ponyfish
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus harak*	LC	Thumbprint emperor
Actinopterygii	Perciformes	Lethrinidae	*Lethrinus nebulosus*	LC	Spangled emperor
Gastropoda	Littorinimorpha	Littorinidae	*Littoraria undulata*	LC	Na
Magnoliopsida	Myrtales	Combretaceae	*Lumnitzera racemosa*	LC	Na
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus argentimaculatus*	LC	Mangrove red snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus ehrenbergii*	LC	Blackspot snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulviflamma*	LC	Dory snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus fulvus*	LC	Blacktail snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus johnii*	LC	John's snapper
Actinopterygii	Perciformes	Lutjanidae	*Lutjanus sebae*	LC	Red emperor snapper
Mammalia	Carnivora	Mustelidae	*Lutra lutra*	NT	Eurasian otter
Mammalia	Carnivora	Mustelidae	*Lutrogale perspicillata*	VU	Smooth-coated Otter
Mammalia	Primates	Cercopithecidae	*Macaca mulatta*	LC	Rhesus monkey
Chondrichthyes	Myliobatiformes	Dasyatidae	*Maculabatis gerrardi*	EN	Whitespotted whipray
Actinopterygii	Elopiformes	Megalopidae	*Megalops cyprinoides*	DD	Indo-pacific tarpon
Aves	Coraciiformes	Meropidae	*Merops albicollis*	LC	White-throated Bee-eater
Aves	Coraciiformes	Meropidae	*Merops nubicus*	LC	Northern Carmine Bee-eater
Aves	Coraciiformes	Meropidae	*Merops persicus*	LC	Blue-cheeked Bee-eater
Aves	Coraciiformes	Meropidae	*Merops superciliosus*	LC	Olive Bee-eater
Aves	Suliformes	Phalacrocoracidae	*Microcarbo africanus*	LC	Long-tailed Cormorant
Actinopterygii	Perciformes	Monodactylidae	*Monodactylus argenteus*	LC	Silver moony
Actinopterygii	Gobiiformes	Gobiidae	*Mugilogobius mertoni*	LC	Merton's mangrove goby
Actinopterygii	Siluriformes	Bagridae	*Mystus gulio*	LC	Na
Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Negaprion* acutidens	EN	Sharptooth lemon shark
Actinopterygii	Clupeiformes	Clupeidae	*Nematalosa nasus*	LC	Bloch's gizzard shad
Mammalia	Cetartiodactyla	Phocoenidae	*Neophocaena phocaenoides*	VU	Indo-pacific finless porpoise

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Perciformes	Labridae	*Novaculichthys macrolepidotus*	LC	Green-banner wrasse
Aves	Charadriiformes	Scolopacidae	*Numenius arquata*	NT	Eurasian curlew
Aves	Charadriiformes	Scolopacidae	*Numenius phaeopus*	LC	Whimbrel
Aves	Pelecaniformes	Ardeidae	*Nycticorax nycticorax*	LC	Black-crowned Night-heron
Actinopterygii	Gobiiformes	Eleotridae	*Ophiocara porocephala*	LC	Spangled gudgeon
Aves	Passeriformes	Oriolidae	*Oriolus larvatus*	LC	Eastern Black-headed Oriole
Actinopterygii	Perciformes	Apogonidae	*Ostorhinchus lateralis*	LC	Humpback cardinal
Actinopterygii	Perciformes	Sciaenidae	*Otolithes cuvieri*	LC	Lesser tiger toothed croaker
Aves	Strigiformes	Strigidae	*Otus senegalensis*	LC	African Scops-owl
Actinopterygii	Gobiiformes	Gobiidae	*Oxyurichthys ophthalmonema*	LC	Eyebrow goby
Aves	Accipitriformes	Pandionidae	*Pandion haliaetus*	LC	Osprey
Mammalia	Carnivora	Felidae	*Panthera pardus*	VU	Leopard
Mammalia	Primates	Cercopithecidae	*Papio cynocephalus*	LC	Yellow baboon
Actinopterygii	Gobiiformes	Gobiidae	*Parachaeturichthys polynema*	LC	Lancet-tail Goby
Actinopterygii	Perciformes	Mullidae	*Parupeneus barberinus*	LC	Dash-and-dot goatfish
Aves	Passeriformes	Paridae	*Parus major*	LC	Great tit
Chondrichthyes	Myliobatiformes	Dasyatidae	*Pastinachus ater*	VU	Broad cowtail ray
Chondrichthyes	Myliobatiformes	Dasyatidae	*Pateobatis bleekeri*	EN	Bleeker's whipray
Aves	Pelecaniformes	Pelecanidae	*Pelecanus rufescens*	LC	Pink-backed Pelican
Actinopterygii	Clupeiformes	Pristigasteridae	*Pellona ditchela*	LC	Indian pellona
Actinopterygii	Perciformes	Sciaenidae	*Pennahia anea*	LC	Grey fin jew fish
Actinopterygii	Gobiiformes	Gobiidae	*Periophthalmus argentilineatus*	LC	Barred mudskipper
Actinopterygii	Gobiiformes	Gobiidae	*Periophthalmus kalolo*	LC	Kalolo mudskipper
Actinopterygii	Gobiiformes	Gobiidae	*Periophthalmus waltoni*	LC	Walton's mudskipper
Aves	Passeriformes	Phylloscopidae	*Phylloscopus collybita*	LC	Common chiffchaff
Aves	Passeriformes	Phylloscopidae	*Phylloscopus nitidus*	LC	Green warbler
Aves	Passeriformes	Phylloscopidae	*Phylloscopus tristis*	LC	Siberian chiffchaff
Aves	Passeriformes	Phylloscopidae	*Phylloscopus trochiloides*	LC	Greenish warbler
Aves	Passeriformes	Phylloscopidae	*Phylloscopus trochilus*	LC	Willow warbler
Gastropoda	Sorbeoconcha	Potamididae	*Pirenella conica*	LC	Na
Actinopterygii	Mugiliformes	Mugilidae	*Planiliza subviridis*	LC	Greenback mullet
Aves	Pelecaniformes	Threskiornithidae	*Platalea leucorodia*	LC	Eurasian spoonbill
Actinopterygii	Perciformes	Ephippidae	*Platax orbicularis*	LC	Orbiculate batfish
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus gibbosus*	LC	Brown sweetlips
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus pictus*	LC	Trout sweetlips
Actinopterygii	Perciformes	Haemulidae	*Plectorhinchus plagiodesmus*	LC	Barred rubberlip

Class	Order	Family	Scientific name	RLTS category	Common name
Actinopterygii	Siluriformes	Ariidae	*Plicofollis dussumieri*	LC	Blacktip sea catfish
Aves	Passeriformes	Ploceidae	*Ploceus nigricollis*	LC	Black-necked Weaver
Aves	Charadriiformes	Charadriidae	*Pluvialis fulva*	LC	Pacific golden plover
Aves	Passeriformes	Cisticolidae	*Prinia gracilis*	LC	Graceful prinia
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis pristis*	CR	Largetooth sawfish
Chondrichthyes	Rhinopristiformes	Pristidae	*Pristis zijsron*	CR	Green sawfish
Actinopterygii	Gobiiformes	Gobiidae	*Psammogobius biocellatus*	LC	Sleepy goby
Actinopterygii	Pleuronectiformes	Paralichthyidae	*Pseudorhombus arsius*	LC	Largetooth flounder
Aves	Passeriformes	Pycnonotidae	*Pycnonotus leucotis*	LC	White-eared Bulbul
Reptilia	Squamata	Pythonidae	*Python sebae*	NT	Central african rock python
Mammalia	Chiroptera	Pteropodidae	*Rousettus aegyptiacus*	LC	Egyptian fruit bat
Actinopterygii	Clupeiformes	Clupeidae	*Sardinella albella*	LC	White sardinella
Actinopterygii	Clupeiformes	Clupeidae	*Sardinella melanura*	LC	Blacktip sardinella
Actinopterygii	Aulopiformes	Synodontidae	*Saurida nebulosa*	LC	Clouded lizardfish
Actinopterygii	Perciformes	Scatophagidae	*Scatophagus argus*	LC	Spotted scat
Anthozoa	Scleractinia	Siderastreidae	*Siderastrea savignyana*	LC	Na
Mammalia	Cetartiodactyla	Delphinidae	*Sousa plumbea*	EN	Indian ocean humpback dolphin
Mammalia	Cetartiodactyla	Suidae	*Sus scrofa*	LC	Wild boar
Aves	Passeriformes	Macrosphenidae	*Sylvietta leucopsis*	LC	Eastern crombec
Actinopterygii	Gobiiformes	Gobiidae	*Taenioides cirratus*	DD	Whiskered eel goby
Chondrichthyes	Myliobatiformes	Dasyatidae	*Taeniura lymma*	LC	Bluespotted lagoon ray
Actinopterygii	Tetraodontiformes	Tetraodontidae	*Takifugu oblongus*	LC	Lattice blaasop
Liliopsida	Alismatales	Cymodoceaceae	*Thalassodendron ciliatum*	LC	Species code: Tc
Aves	Pelecaniformes	Threskiornithidae	*Threskiornis aethiopicus*	LC	African sacred ibis
Actinopterygii	Clupeiformes	Engraulidae	*Thryssa baelama*	LC	Baelama anchovy
Aves	Coraciiformes	Alcedinidae	*Todiramphus chloris*	LC	Collared kingfisher
Aves	Charadriiformes	Scolopacidae	*Tringa nebularia*	LC	Common greenshank
Reptilia	Testudines	Trionychidae	*Trionyx triunguis*	VU	African softshell turtle
Actinopterygii	Gobiiformes	Gobiidae	*Trypauchen vagina*	LC	Burrowing goby
Chondrichthyes	Myliobatiformes	Dasyatidae	*Urogymnus granulatus*	VU	Mangrove whipray
Actinopterygii	Anguilliformes	Muraenidae	*Uropterygius concolor*	LC	Brown moray eel
Reptilia	Squamata	Varanidae	*Varanus niloticus*	LC	Nile monitor
Aves	Charadriiformes	Scolopacidae	*Xenus cinereus*	LC	Terek sandpiper
Actinopterygii	Gobiiformes	Gobiidae	*Yongeichthys nebulosus*	LC	Shadow goby
Aves	Passeriformes	Zosteropidae	*Zosterops palpebrosus*	LC	Indian White-eye

3. National Estimates for subcriterion A1

To estimate the Arabian (Persian) Gulf mangrove ecosystem extent in 1970, we gathered reliable information on the mangrove area for each country within the province around this period (Table b). We then estimated the mangrove area in 1970 for each country, assuming a linear relationship between mangrove extent and time. Finally, we summed up the country estimates to determine the total mangrove area in the Arabian (Persian) Gulf province (Table a). We assumed that the percentage of mangrove extent by country within the province remained constant over time, as the percentages did not change between 1996 and 2020 (GMW v3.0 dataset). There were some exceptions for countries that observed an increased cover largely due to mangroves plantation and reforestation efforts. These marginal changes were observed for the United Arab Emirates, using high-resolution Landsat imagery, indicate an extent increase of 50.56 km^2 (5056 ha) between 2001 to 2017, acknowledging that mangroves plantation areas contribute to an estimate of 40 % of the area increase (EAD, 2020). Another observed increase according to Naderloo, *et al.*, (2023), mangroves in Iran are roughly 139 km^2 (13,900 ha), however, additional spatial distribution datasets are required to further verify the current extent. Moreover, using mangrove area estimates from different sources can lead to uncertainty (Friess and Webb, 2014)[2] and local or regional scale data may not be available for rest of countries. Thus, the estimates for 1970 should be considered only indicative.

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

Year	Country total 2020*	Within province 2020*	Within province 1970 Least estimate**	Within province 1970 Highest estimate***
Bahrain	0.6	0.6	0.3	1.6
Iran	111.8	111.8	39.5	303.0
Oman	1.4	1.4	0.9	27.10
Pakistan	828.9	7.2	50.7	50.7
Qatar	4.5	4.5	0.15	5.0
Saudi Arabia	76.0	9.5	0.07	26.30
United Arab Emirates	74.5	74.5	9.9	29.24
The Arabian (Persian) Gulf		209.50	101.52	442.94

Table b. List of selected studies considered to have reliable information on mangrove area for the period around 1970 in each country of the Arabian (Persian) Gulf province.

Country	Year	Mangrove Area (Ha)	Reference
Bahrain**	1977	31	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Bahrain**	1989	25	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.

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

Bahrain**	2000	43	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Bahrain**	2017	48	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Bahrain***	1980	150	FAO (2007) The World's Mangroves 1980-2005.
Bahrain***	1990	100	FAO (2007) The World's Mangroves 1980-2005.
Bahrain***	1992	100	FAO (2007) The World's Mangroves 1980-2005.
Bahrain***	2000	90	FAO (2007) The World's Mangroves 1980-2005.
Bahrain***	2005	90	FAO (2007) The World's Mangroves 1980-2005.
Iran**	1977	4735	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Iran**	1989	6052	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Iran**	2000	8015	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Iran**	2017	9403	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Iran***	1980	27500	FAO (2007) The World's Mangroves 1980-2005.
Iran***	1990	22500	FAO (2007) The World's Mangroves 1980-2005.
Iran***	1997	19234	FAO (2007) The World's Mangroves 1980-2005.
Iran***	2000	19100	FAO (2007) The World's Mangroves 1980-2005.
Iran***	2005	19000	FAO (2007) The World's Mangroves 1980-2005.
Oman**	1977	206	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Oman**	1989	153	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Oman**	2000	168	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Oman**	2017	530	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Oman***	1980	2000	FAO (2007) The World's Mangroves 1980-2005.

Oman* **	1990	2000	FAO (2007) The World's Mangroves 1980-2005.
Oman	1992	2000	Sheppard *et al*. (1992). Marine ecology of the Arabian region. Patterns and Process in Extreme tropical Environment. Academic Press London UK 359 pp.
Oman***	1995	1088	FAO (2007) The World's Mangroves 1980-2005.
Oman***	2000	1000	FAO (2007) The World's Mangroves 1980-2005.
Oman***	2005	1000	FAO (2007) The World's Mangroves 1980-2005.
Pakistan	1980	345000	Ministry of Food, Agriculture and Cooperatives, Food and Agriculture Division (2005). Letter of 12/3/81 of Inspector General of Forests/Additional Secretary to Assistant Director General, Forestry Department, FAO on FAO/UNEP Tropical Forest Resources Assessment Project - Islamabad
Pakistan	1985	283000	Kogo, M. (1985). A report of Mangrove research and recommendations of afforestation in Pakistan. UNDP/UNESCO Regional Project on Mangrove Ecosystems of Asia and the Pacific - RAS/72/002; Nov. 1985; Al-Gurm Research Centre for the Middle East, Tokyo. pp i-v 47
Pakistan	1990	207000	Reid, Collins and Associates, Canada, and Silvi consult Ltd. Sweden. (1992). Forestry Sector Master Plan: National Perspective. Islamabad, Pakistan. 195 pp.
Pakistan***	2000	158,000.00	Estimations by FAO (2007) The World's Mangroves 1980-2005.
Pakistan***	2005	157,000.00	Estimations by FAO (2007) The World's Mangroves 1980-2005.
Pakistan***	2001	158,000.00	FAO (2007) The World's Mangroves 1980-2005.
Qatar**	1977	16	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Qatar**	1989	184	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Qatar**	2000	283	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Qatar**	2017	1002	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Qatar	1992	500	Spalding, M.D., Blasco, F. and Field, C.D., eds. 1997. World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp.
Qatar***	1980 - 2005	500	FAO (2007). 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.
Saudi Arabia**	1977	97	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Saudi Arabia**	1989	107	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Saudi Arabia**	2000	146	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
Saudi Arabia**	2017	837	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.

Saudi Arabia* **	1980	21000	FAO (2007). 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.
Saudi Arabia* **	1990	20000	FAO (2007). 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.
Saudi Arabi*a**	2000	20000	FAO (2007). 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.
Saudi Arabia* **	2005	20000	FAO (2007). 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.
Saudi Arabia* **	1985	20400	Saenger, P. (1993). Management of Mangroves in the Kingdom of Saudi Arabia.
United Arab Emirates **	1977	1327	Milani, A. S. (2018). Mangrove Forests of the Persian Gulf and the Gulf of Oman. In Threats to Mangrove Forests, edited by Christopher Makowski and Charles W. Finkl, 25:53–75. Coastal Research Library. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73016-5_3.
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