

REGIONAL REPORT V.0

Red List of Ecosystems assessment of ROPME Sea Area coral reefs

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KEYWORDS

Red List of Ecosystems; coral reefs; ecosystem collapse; risk assessment; ROPME Sea Area

ABSTRACT

Coral reefs of the ROPME Sea Area (RSA) extend from the Arabian (Persian) Gulf through the Gulf of Oman to the western Arabian Sea, spanning the coastal and offshore waters of Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. With an area of 632 km², these coral reefs represent 0.35% of the photic coral reef area assessed globally in the Red List of Ecosystems. Six ecoregions were defined using the Marine Ecoregions of the World framework, with boundaries refined to reflect regional environmental and ecological variation. These ecosystems range from marginal coral veneers adapted to extreme temperatures and salinity to structurally complex framework-building reefs. Environmental conditions range from the shallow, hypersaline Arabian (Persian) Gulf to the monsoon-driven upwelling systems of the Western Arabian Sea. Marine heatwaves are an increasing threat, while pressures from coastal development, dredging, land reclamation, and fishing vary among ecoregions. The IUCN Red List of Ecosystems assessment evaluated reef condition between 1975 and 2025 using historical and contemporary monitoring data, observed Degree Heating Weeks records from 1985-2025 and climate

projections for 2026-2075. All six ecoregions were classified as Critically Endangered overall. This classification integrates historical declines, present condition and geographic distribution under Criteria A, B, C1 and D with projected environmental degradation under subcriterion C2. Across Criteria A, B, C1 and D, three ecoregions were Critically Endangered, two Endangered and one Vulnerable. Subcriterion C2 returned a Critically Endangered result for five ecoregions, elevating the overall classification of three. Western Arabian Sea – North was Not Evaluated under C2 and was classified as Critically Endangered overall because of its restricted distribution under subcriterion B1. As the first region-wide assessment of coral reef collapse risk in the region, this study shows that even highly heat-tolerant coral communities face a high risk of collapse under continued global warming, reinforcing the need for climate action, effective local management and sustained regional monitoring.

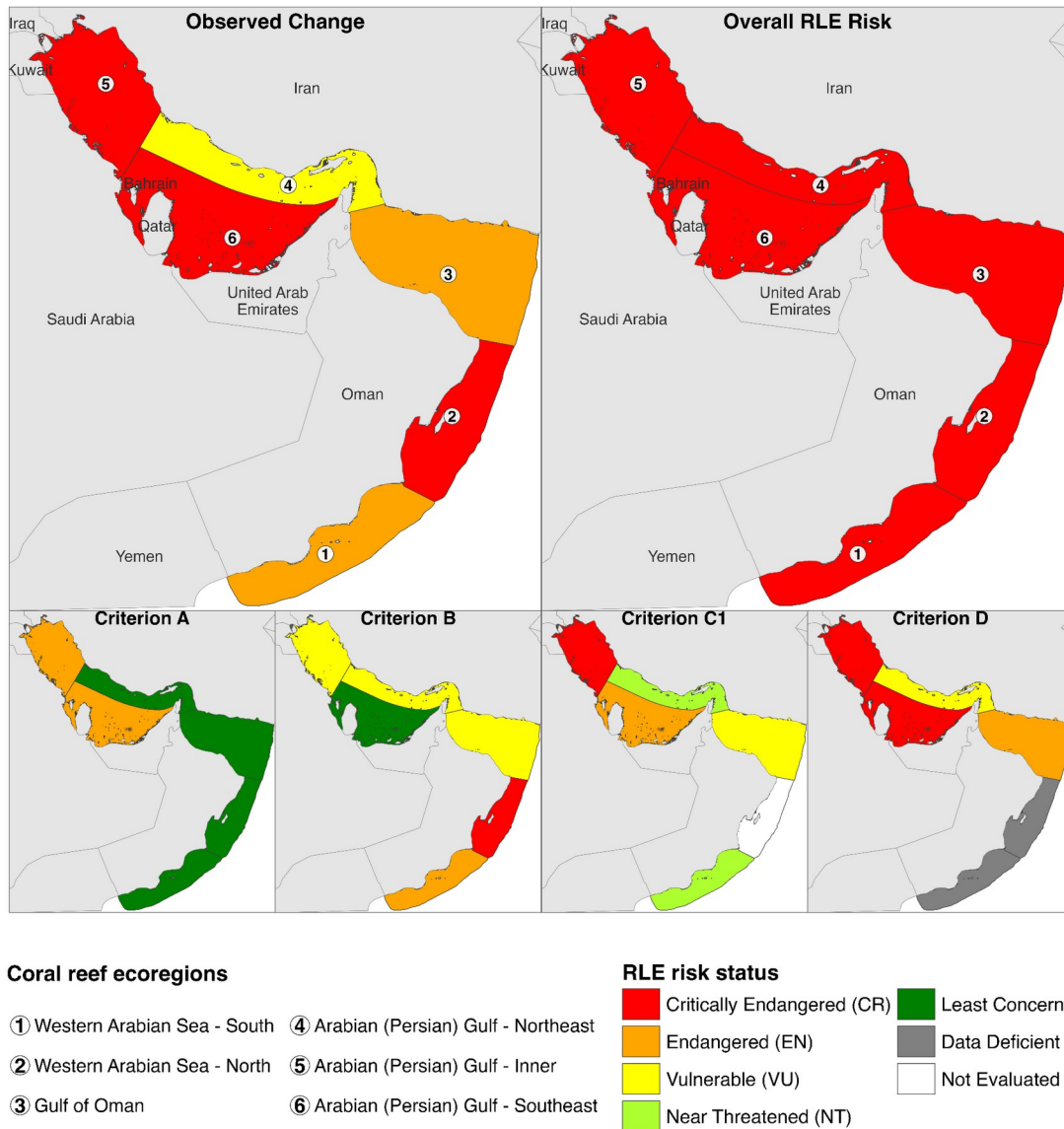


Figure 1. IUCN Red List of Ecosystems risk classification for the six coral reef ecoregions of the ROPME Sea Area. The upper-left panel shows the highest risk category under Criteria A, B, C1 and D (Risk from observed changes). The upper-right panel shows the overall RLE classification across all criteria, including projected environmental degradation under subcriterion C2 for 2026-2075 (all ecoregions classified as CR under C2). The lower panels show the individual classifications under Criteria A, B, C1 and D.

1. Study Area

This Red List of Ecosystems (RLE) assessment evaluates the risk of collapse for coral reefs across the ROPME Sea Area (RSA) as of 2025. RSA coral reefs (IUCN Global Ecosystem Typology M1.3 - photic coral reefs) extend across the semi-enclosed marine systems of the Arabian (Persian) Gulf, Gulf of Oman and the western Arabian Sea, approximately between 15.9°N and 30.5°N and 47.7°E and 61.4°E. The assessment encompasses coastal and offshore waters of Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates, and includes true reefs,

marginal reef systems, and coral communities associated with seamount and offshore hardground habitats. Overall, the region contains an estimated 632 km² of coral reefs, representing 0.7% of the global coral reef extent.

Coral reefs of the RSA were initially grouped into three ecoregions based on the Marine Ecoregions of the World (MEOW) framework (Spalding et al. 2007), with subsequent subdivision into six units of assessment, with refinement of boundaries to better reflect regional physico-ecological patterns (Figure 2). The boundaries were refined using published regional biogeographic studies together with expert review to better represent spatial variation in coral biodiversity, oceanographic conditions and environmental drivers across the region (Claereboudt & Bruss 2025; Rezai et al. 2004; Riegl & Purkis 2012; Sheppard et al. 2010). The resulting ecoregions capture regional variation in coral reef biodiversity, abiotic conditions (including temperature, salinity, turbidity and oceanographic gradients), differences in exposure to anthropogenic and climatic threats, and are equivalent to Level 4 of the IUCN Global Ecosystem Typology (regional sub-groups).

All six ecoregions were treated as regional variants of the M1.3 Photic coral reefs ecosystem functional group. Within the RSA, these ecosystems range from well-developed framework-building reefs to marginal, low-relief coral veneers with limited carbonate accretion and topographic development. These forms were included because hard corals remain defining components of the ecosystem and support characteristic habitat-forming and ecological functions, although carbonate production, framework development and structural complexity vary considerably. Coral reefs in each ecoregion were assessed independently using the IUCN Red List of Ecosystems criteria (details on data collection/monitoring in Annex 1).

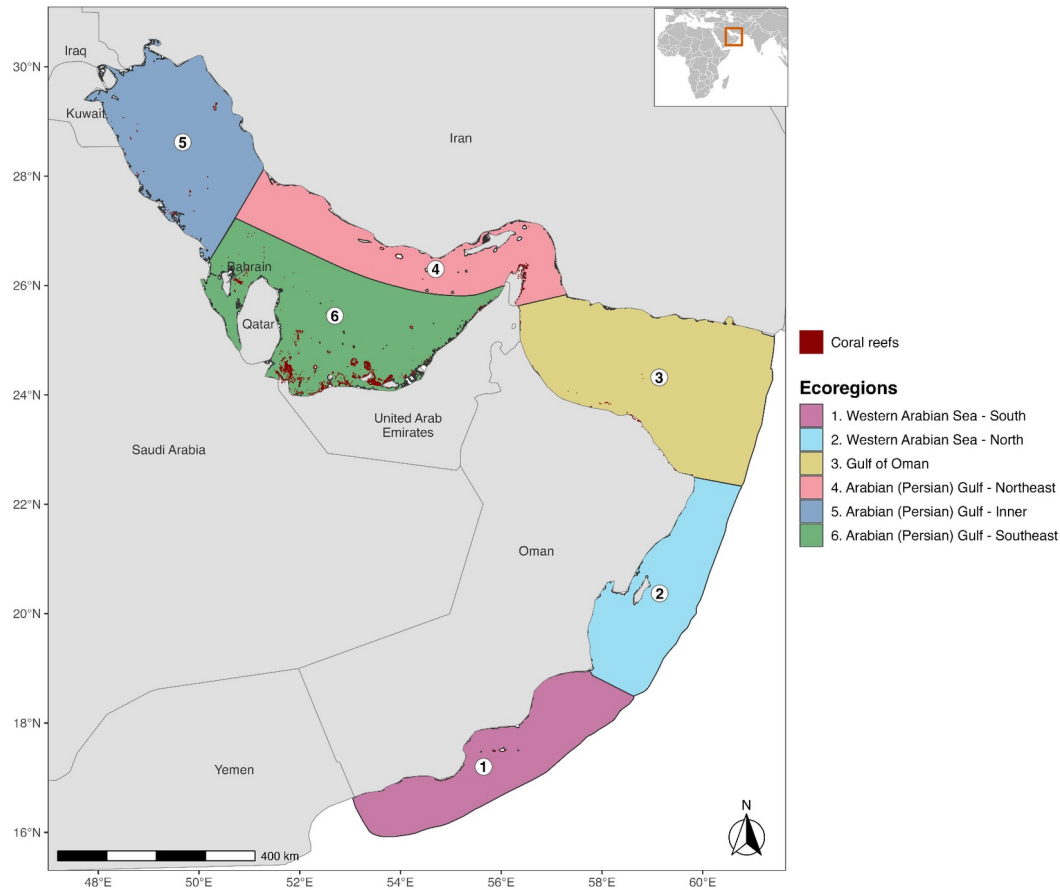


Figure 2. Coral reefs of the **ROPME Sea Area**, grouped within coral reef ecoregions (Units of Assessment) to be evaluated under the IUCN Red List of Ecosystems criteria and corresponding to Level 4 of the IUCN Global Ecosystem Typology.

2. Ecosystem Description

Coral reefs occur in all eight nations bordering the ROPME Sea Area (RSA), ranging from marginal, low-relief coral veneers with limited framework development to structurally complex, framework-building reefs (Burt et al., 2016; Rezai et al., 2004; Sheppard & Salm, 1988). True framework-building reefs are unevenly distributed throughout the region, occurring around offshore islands in Kuwait and Saudi Arabia, the Musandam Peninsula, parts of the Gulf of Oman, and specific sheltered locations along the Arabian Sea coast (Basson & Bobrowski, 1977; Claereboudt & Bruss 2025; Sheppard & Salm 1988). In contrast, a substantial portion of the regional coral habitat consists of marginal, low-relief “coral carpet” systems, where corals form a thin veneer over rocky substrates (Purkis & Riegl, 2005). These communities are particularly common in areas of environmental extremes, such as the thermally variable and extreme southern Arabian (Persian) Gulf and the cool, monsoon-influenced Dhofar coast of the Arabian Sea. Together, both reef-building and marginal coral communities support distinct coral reef assemblages across the region (Claereboudt, 2019; Riegl & Purkis, 2012).

2.1. Key Biotic Components

Coral species diversity declines markedly across the RSA in response to pronounced environmental gradients such as temperature, salinity and turbidity. Species richness is highest in the Western Arabian Sea ecoregions (> 140 coral species), decreases to approximately 120 species in the Gulf of Oman, and declines further within the Arabian (Persian) Gulf, where increasingly extreme environmental conditions limit coral diversity, from ~70 species in the Northeastern Gulf to ~50 in the Inner Gulf and ~34 in the Southeast Gulf (Burt, 2024; Claereboudt, 2019; Shokri & Kabiri, 2025b). Nevertheless, even the most species-rich ecoregions remain well below that of the Coral Triangle (>500 coral species), the global centre of coral diversity (Veron et al., 2009).

Coral assemblages are largely structured by local environmental conditions and disturbance history. In less environmental extreme ecoregions, including the offshore islands of the Northeastern Gulf and parts of the Gulf of Oman, coral communities were historically dominated by structurally complex tabular and branching *Acropora* and *Pocillopora* (Hadj-Hammou et al., 2025; Pratchett et al., 2017; Shokri & Kabiri, 2025a). Comparable *Acropora*-dominated assemblages were historically widespread in the Southeast Gulf, but recurrent bleaching since 1996 has caused substantial ecological restructuring, leaving remnant communities on some protected offshore reefs (Bejarano et al., 2022; Burt et al., 2011; Burt & Bauman 2020; Riegl 2002). Over the past three decades, coral assemblages across much of the Gulf have shifted toward stress-tolerant massive taxa, primarily *Porites*, *Platygyra*, *Dipsastraea*, *Favites*, and *Cyphastrea*, with many reefs at lower live coral cover than historically (Burt & Paparella, 2023; Figure 3). The region supports relatively few coral species with restricted geographic distributions. Several taxa, including *Acropora arabensis*, *Acropora downingi* and *Porites harrisoni*, have historically been regarded as regional endemics, although their taxonomic status and geographic distributions remain under review (Coles, 2003; Riegl & Purkis, 2012; Sheppard et al., 2012; Torquato et al., 2022). In contrast, coral assemblages in the Arabian Sea are strongly shaped by the seasonal monsoon. Along the Dhofar coast, seasonal upwelling restricts coral development to marginal, low-relief coral carpet communities that coexist with canopy-forming macroalgae, while the Bar Al Hikman Peninsula remains a rare exception, supporting massive monospecific true reef frameworks of *Montipora foliosa* (Claereboudt, 2019; Salm 1993).

In addition to reef-building corals, several other benthic groups contribute to the structure and functioning of RSA reefs. Crustose coralline algae promote coral settlement and reef framework development, while soft corals are particularly characteristic of the Gulf of Oman and the Strait of Hormuz, contributing to regional variation in benthic community composition (Bento et al., 2017; Samimi-Namin & Van Ofwegen, 2012). Macroalgae form an important component of benthic assemblages in the seasonally upwelling Arabian Sea, whereas echinoderms, particularly sea urchins, are important grazers and bioeroders across several Gulf ecoregions (Lin et al., 2021; Riegl & Purkis, 2012). Sponges are also common reef-associated organisms throughout the region, although their diversity and ecological roles remain comparatively poorly documented (Erpenbeck et al., 2016, 2020; Lin et al., 2022). Branching corals contribute disproportionately to three-dimensional reef habitat complexity and provide important habitat for reef-associated organisms (Oh et al., 2025), while coral cover, hard-bottom extent and structural complexity shape local reef-fish assemblages (Kembrey et al., 2024).

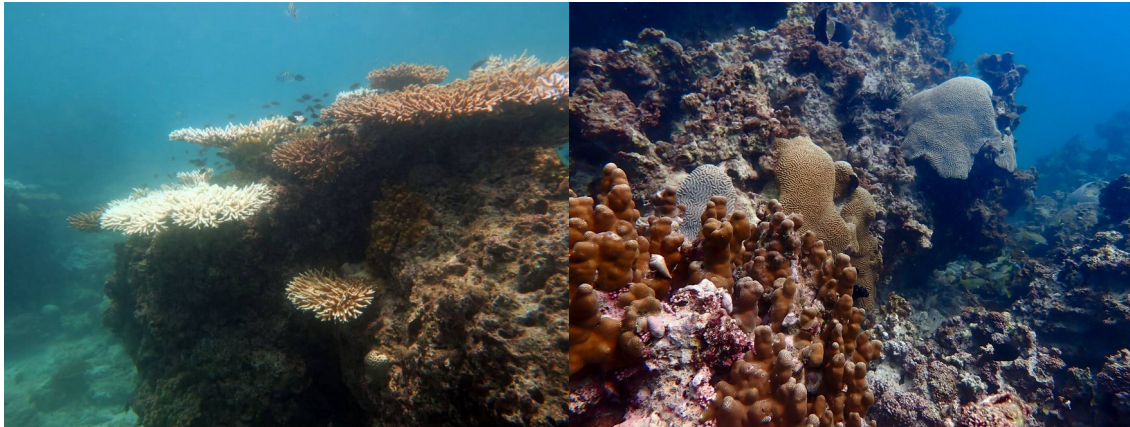


Figure 3. Contrasting coral assemblages in the Arabian (Persian) Gulf. Left: structurally complex *Acropora* assemblages showing partial bleaching at Kish in the Northeast Gulf, Iran, in 2026 (photo: Saeed Parvin). Right: coral community characterised by stress-tolerant corals at Delma Island in the Southeast Gulf, United Arab Emirates, in 2024 (photo: Rebekka Pentti).

Reef fish diversity appears to follow a similar regional pattern to corals, declining from the Western Arabian Sea through the Gulf of Oman to the Arabian (Persian) Gulf. Available evidence indicates that reef-fish communities in the Arabian (Persian) Gulf are generally less species-rich and lower in abundance and biomass than those of the Gulf of Oman and the Western Arabian Sea (Burt 2015; Burt et al., 2011; Randall, 1995). In the environmentally extreme southern Arabian (Persian) Gulf, trophic structure differs markedly from typical Indo-Pacific reefs, with relatively few species, predominantly generalists, and reduced functional redundancy (Brandl et al., 2020; Feary et al., 2012). Despite the various environmental pressures, the RSA supports several endemic fish species, including the Oman anemonefish (*Amphiprion omanensis*) and the Gulf parrotfish (*Scarus persicus*), as well as threatened and heavily exploited reef-fish species (Bejarano et al., 2025; Claereboudt, 2019; Kembrey et al., 2024). Furthermore, these reefs provide foraging habitat for globally threatened megafauna, including the reef-resident hawksbill turtle (*Eretmochelys imbricata*), the green turtle (*Chelonia mydas*) and various reef-associated elasmobranchs (Jabado et al., 2021; Pilcher et al., 2014).

2.2. Key Abiotic components

The RSA encompasses a wide range of oceanographic and environmental conditions, from the monsoon-influenced Arabian Sea to the shallow, semi-enclosed Arabian (Persian) Gulf. These contrasting physical settings generate pronounced gradients in temperature, salinity, productivity, turbidity and hydrodynamic conditions that shape coral reef distribution and ecosystem structure across the region. Together, these contrasting oceanographic regimes underpin the distinct abiotic environments represented by the six coral reef ecoregions recognized in this assessment. The Western Arabian Sea ecoregions are strongly influenced by the seasonal Indian Ocean Monsoon, which drives coastal upwelling, nutrient enrichment, elevated biological productivity and strong seasonal wave exposure (Glynn, 1993; Ismail & Shehhi, 2022; Wiggert et al., 2005). This system can drop sea surface temperatures to as low as 16°–19°C during the summer months while simultaneously having elevated nutrient levels (Al-Jufaili et al., 1999; Glynn, 1993). This oceanic influence continues into the Gulf of Oman, which is characterized by stable salinities of approximately 36 practical salinity units (psu) and significant bathymetric complexity (Claereboudt, 2019). While this ecoregion avoids the extreme cold of the southern

upwelling, it remains influenced by high water clarity and oceanic swell, with reef development generally restricted to a narrow vertical band along the coast.

The Strait of Hormuz acts as a critical hydrographic gateway where oceanic water enters and exits the shallow, semi-enclosed basin of the Arabian (Persian) Gulf. Because evaporation within the Gulf significantly exceeds freshwater input, the basin functions as an inverted estuary where salinity increases as water moves away from the Strait (Johns et al., 2003; Riegl & Purkis, 2012). Following the basin's anticlockwise circulation, abiotic conditions change as the water first moves towards the Northeastern Gulf. Here, the Iranian Coastal Current introduces comparatively cooler, less saline oceanic water into the basin, though the area is characterized by high tidal ranges and periodic sub-aerial exposure of reef flats (Kavousi et al., 2014). As the current continues into the Northwestern Gulf, it was historically influenced by the freshwater and sediment discharge of the Shatt al-Arab. However, recent upstream damming and diversions have reduced this input, leading to increased salinity and altered turbidity regimes in the waters of Kuwait and northern Saudi Arabia (Al-Ghadban & El-Sammak, 2005). In the final stage of the circulation, the water reaches the shallow Southern Gulf basin where evaporation is highest. This ecoregion experiences the most extreme thermal and saline conditions globally, with temperatures ranging from 18°C in winter to over 36°C in summer and salinities exceeding 45 psu (Burt & Paparella, 2024). These conditions are further exacerbated by *Shamal* winds, which drive localised wave action and high sediment resuspension, resulting in the most environmentally restricted reef habitats in the RSA (Riegl & Purkis, 2012).

2.3. Key processes and interactions

Connectivity and recovery in the RSA are strongly influenced by oceanographic features that regulate larval exchange among coral reef populations. The Ras Al Hadd Jet in the Northwestern Arabian Sea and the Strait of Hormuz act as important, species-dependent barriers for larval exchange, influencing connectivity between the Arabian Sea, Gulf of Oman and the Arabian (Persian) Gulf (Cavalcante et al., 2020; Claereboudt & Bruss, 2025; Smith et al., 2022; Torquato & Møller, 2020). The permeability of these barriers varies among taxa according to larval traits, including pelagic larval duration and behaviour (Torquato & Møller, 2020). Superimposed on these connectivity patterns, regional environmental gradients in temperature, salinity and turbidity influence recruitment, community composition and recovery following disturbances, contributing to the marked ecological differences among ecoregions.

Competition between corals and algae is an important process influencing benthic community dynamics throughout the RSA. Seasonal nutrient enrichment and favourable growth conditions can promote macroalgal proliferation in the northern Gulf and southern Oman, and the persistence of algal communities is strongly influenced by herbivory (Foster et al., 2012; Sheppard et al., 2012). In contrast, in the more thermally extreme Southern Gulf, turf algae play a more persistent role as the primary space occupier (Foster et al., 2012; Sheppard et al., 2012). Top-down control of these algal communities varies significantly across the region. While herbivorous fish are important in much of the RSA, their assemblages are often species-poor and low in abundance at southern Gulf, where high sea urchin density (primarily *Echinometra* sp. *EZ*) may partially compensate for the low fish grazing (Feary et al., 2010; Foster et al., 2012; Hoey et al., 2016; Riegl & Purkis, 2012).

Larval supply and recruitment dynamics remain a critical knowledge gap for much of the region. Settlement studies focused on the Southern Gulf indicate extremely low levels of larval recruitment, which likely constrains the recovery of reefs following mass mortality events (Bauman et al., 2014; Bento et al., 2017). While modeling studies suggest that offshore islands may function as essential larval sources for coastal reefs within the Gulf (Bento et al., 2021; Cavalcante et al., 2016), dynamics in the Gulf of Oman and Arabian Sea are less understood. Preliminary evidence from the Gulf of Oman suggests that complex coastal currents may lead to high larval export, potentially leaving some reef systems isolated despite their proximity to one another (Claereboudt, 2019).

The structural persistence of RSA coral reefs relies on the precarious balance between carbonate production and destructive processes. Bioerosion by urchins and boring sponges is notably high in the thermally extreme Southern Gulf, often matching or exceeding vertical coral growth rates (Al-Mansoori et al., 2020; Riegl & Purkis, 2012). Recent work from Bahrain shows that bleaching can severely reduce reef carbonate production, with shallow nearshore reefs dropping from positive to near-neutral carbonate budgets after the 2017 heat event (AlMealla et al., 2024).

2.4. Main Threats

Coral reefs across the RSA are subject to a combination of acute climate disturbances and chronic anthropogenic pressures, although the relative importance of these threats varies among ecoregions because of contrasting environmental conditions and human pressures (Table 1). The Western Arabian Sea ecoregions are strongly influenced by the seasonal Indian Ocean Monsoon and are therefore particularly sensitive to changes in upwelling dynamics and regional oceanographic conditions (Claereboudt, 2019; Glynn, 1993; Wiggert et al., 2005). In addition to climate-related changes, fishing pressure represents an important anthropogenic threat to reef-associated communities (Burt et al., 2016). Reefs are also exposed to acute damage from tropical cyclones and, locally, recent coastal development. In Western Arabian Sea–North, expanding aquaculture and tourism place additional pressure on geographically restricted coral communities.

The Gulf of Oman is exposed to a broader range of local anthropogenic pressures. Rapid coastal development has resulted in localised sedimentation and pollution, while tourism-related activities, including anchor damage, affect reefs in areas such as the Daymaniyat Islands Nature Reserve (Al-Jufaili et al., 1999). Abandoned or lost fishing gear can cause additional physical damage to reef habitat (Figure 4, left). These ecoregions are also periodically affected by tropical cyclones, harmful algal blooms, including the 2008–2009 regional event, and localised outbreaks of the crown-of-thorns starfish (*Acanthaster* spp.), which have caused significant coral mortality in parts of the Gulf of Oman and the Strait of Hormuz (Glynn 1993; Mendonça et al., 2010; Richlen et al., 2010; Seveso et al., 2024).

Within the Arabian (Persian) Gulf, increasingly frequent and severe marine heatwaves represent the dominant climate-related threat and have caused extensive coral mortality and long-term shifts in community composition, particularly through the loss of structurally complex *Acropora* assemblages (Burt et al., 2011; Burt & Bauman, 2020; Burt & Paparella, 2023; Riegl, 2002). Although coral communities in parts of the Gulf are now dominated by relatively heat-tolerant species, repeated marine heatwaves are increasingly exceeding the thermal limits of even these corals (Figure 4, right). Periods of elevated summer temperatures and environmental stress have

also been associated with localised coral disease outbreaks (Aeby et al., 2020; Howells et al., 2020). In developed coastal areas, these pressures are further compounded by dredging and land reclamation, which have caused direct habitat loss, while desalination and oil and gas activities contribute additional cumulative pressures across the Gulf (Al-Mutairi 2025; Burt 2014; Moradi et al., 2014; Oladi & Shokri, 2020; Sheppard, 2012). In the Inner Gulf, upstream damming and water diversion have substantially reduced freshwater and sediment discharge from the Shatt al-Arab, altering salinity and turbidity regimes (Al-Ghadban & El-Sammak, 2005). Across parts of the Gulf, overfishing of key functional groups, particularly herbivores and piscivores, further compromises ecosystem resilience. The loss of herbivores reduces grazing pressure, while the depletion of piscivores alters trophic structure and functional diversity, potentially limiting reef recovery from recurring thermal disturbances (Feary et al., 2010; Grandcourt 2012; Wabnitz et al., 2018). The principal biotic and abiotic characteristics and key threats of the six coral reef ecoregions are summarised in Table 2. The interactions among these ecosystem components, ecological processes, drivers and threats are illustrated in the conceptual model (Figure 5).

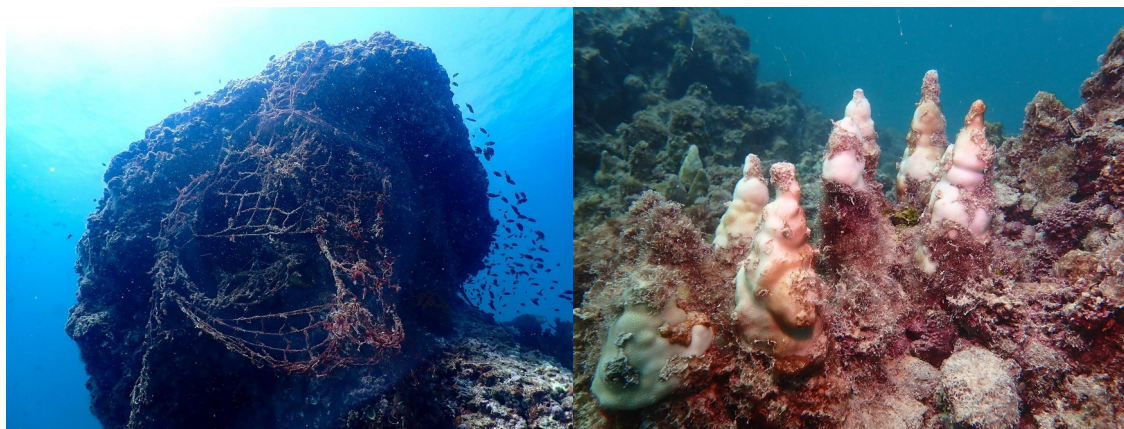


Figure 4. Examples of climate-related and local pressures affecting coral reefs in the ROPME Sea Area. Left: an abandoned fishing net entangled on reef habitat in the Daymaniyat Island Nature Reserve, Oman, in 2022. Right: bleaching affecting *Porites* colonies at Al Dhabiya Reef, United Arab Emirates, in 2023 (photos: Rebekka Pentti).

Coral reefs across the RSA are managed through national legislation, marine protected areas and other national measures. At the regional level, cooperation is supported by Kuwait Regional Convention and its Protocol concerning the Conservation of Biological Diversity and the Establishment of Protected Areas. These arrangements support cooperation among countries in protecting shared reef ecosystems and addressing pressures that extend across national boundaries.

Table 1. Occurrence of major threats potentially impacting coral reefs in each ecoregion categorised based on the IUCN Threat Classification Scheme. List of Ecoregions: 1) Western Arabian Sea – South; 2) Western Arabian Sea – North; 3) Gulf of Oman; 4) Arabian (Persian) Gulf – Northeast; 5) Arabian (Persian) Gulf – Inner; 6) Arabian (Persian) Gulf – Southeast. ✓ Current major threat; + recently documented or emerging threat; – not known to be a significant threat.

Threat type	Subcategory	Ecoregion					
		1	2	3	4	5	6
1. Residential & commercial development	1.1 Housing & urban areas	+	✓	✓	+	–	✓
	1.2 Commercial & Industrial Areas	+	✓	✓	✓	+	✓
	1.3 Tourism & recreation areas	+	+	✓	✓	–	✓
2. Agriculture & aquaculture	2.4 Marine & freshwater aquaculture	+	✓	✓	+	–	–
3. Energy production & mining	3.1 Oil & gas drilling	–	✓	✓	✓	✓	✓
4. Transportation & service corridors	4.3 Shipping lanes	–	✓	✓	✓	✓	✓
5. Biological resource use	5.4 Fishing & harvesting aquatic resources	✓	✓	✓	✓	✓	✓
6. Human intrusions & disturbance	6.1 Recreational activities	+	✓	✓	✓	–	–
7. Natural system modifications	7.3 Other ecosystem modifications	+	+	✓	+	–	✓
8. Invasive & problematic species	8.1 Invasive non-native species	✓	–	✓	✓	✓	✓
	8.2 Problematic native species	–	–	✓	+	+	✓
9. Pollution	9.1 Domestic & urban waste water	+	+	✓	✓	✓	–
	9.2 Industrial & military effluents (Oil spills)	✓	✓	✓	✓	✓	✓
	9.3 Agricultural & forestry effluents	+	–	✓	–	–	–
	9.4 Garbage & Solid waste	✓	✓	✓	✓	+	✓
11. Climate change & severe weather	11.3 Temperature extremes	✓	✓	✓	✓	✓	✓
	11.4 Storms & flooding	✓	✓	✓	✓	–	–

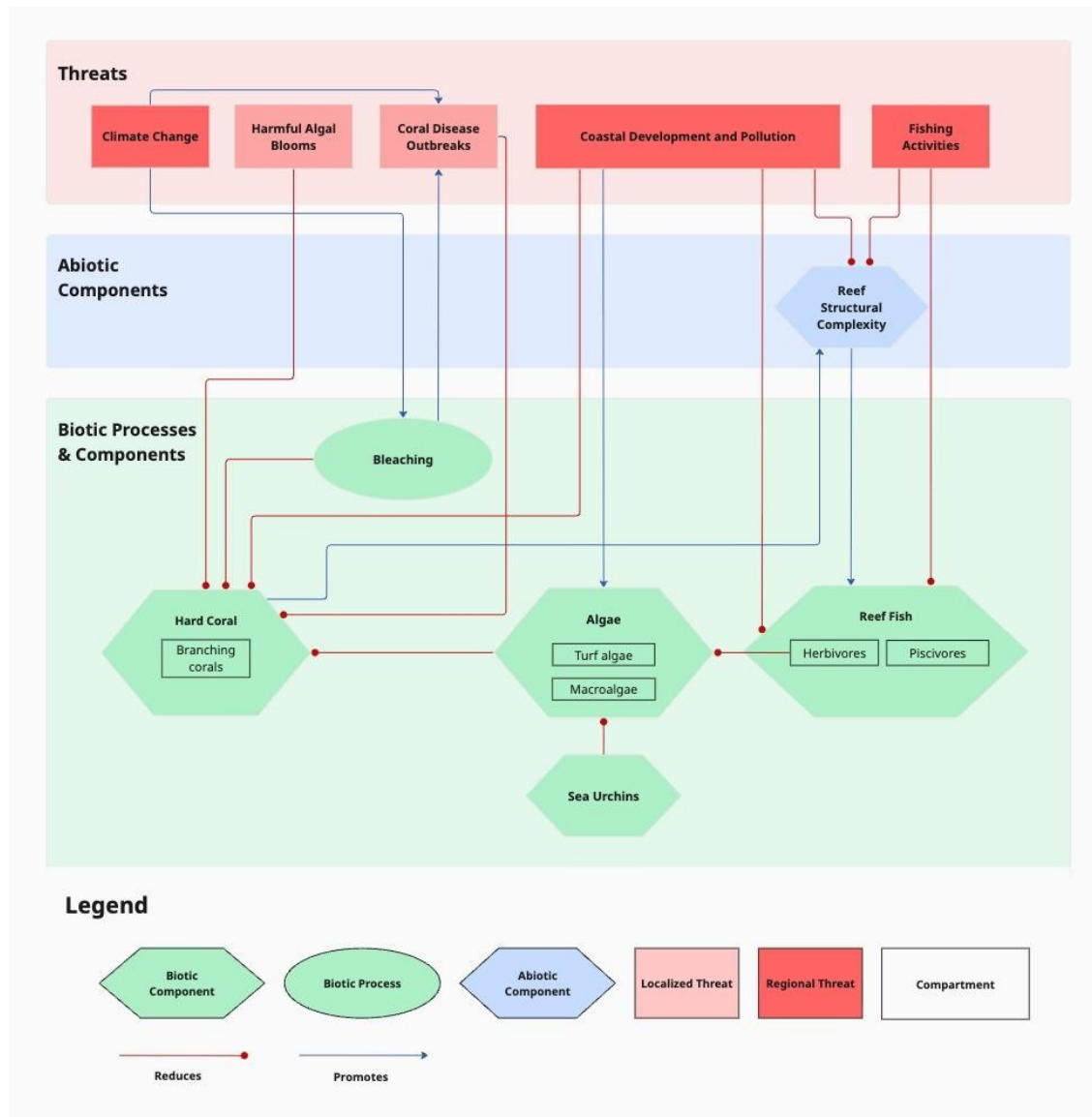


Figure 5. Conceptual model of the ROPME Sea Area coral reef ecosystems. The model illustrates key biotic and abiotic components, as well as external drivers, threats, and the processes and interactions between them. Dark-red boxes represent regional threats, pale-red boxes represent localised threats, red lines indicate negative effects, and blue arrows indicate positive effects.

Table 2. Key biotic and abiotic features and principal threats across the coral reef ecoregions of the **ROPME Sea Area**. The features and threats presented highlight important differences among ecoregions.

Ecoregion	Key Biotic	Key Abiotic	Key Threats
Western Arabian Sea – South	Predominantly marginal coral communities; seasonal macroalgal-coral assemblages (<i>Nizamuddinia zanardinii</i>); geographically restricted Dhofar parrotfish (<i>Scarus zufar</i>).	Intense seasonal southwest monsoon upwelling; high nutrient availability and primary productivity; heavy wave action; shoaling Oxygen Minimum Zone (OMZ).	Changes in the Indian Ocean monsoon/upwelling regime; fishing pressure (including ghost fishing); acute storm damage (tropical cyclones); localised coastal development.
Western Arabian Sea – North	Predominantly marginal reefs with localised monospecific	Moderate seasonal upwelling; high seasonal	Changes in upwelling dynamics; fishing pressure

Ecoregion	Key Biotic	Key Abiotic	Key Threats
	<i>Montipora foliosa</i> reef frameworks; high coral species richness; seasonal <i>Sargassum</i> and <i>Padina</i> beds.	SST variability; high nutrient availability and primary productivity.	(including ghost fishing); aquaculture expansion; emerging tourism pressure.
Gulf of Oman	Mixed true framework-building and marginal coral reefs; structurally complex <i>Acropora</i> and <i>Platygyra</i> coral assemblages; high biomass of commercially important reef fishes.	Oceanic salinities; seasonal upwelling along parts of the Iranian and Omani coasts; Ras Al Hadd oceanographic transition.	Marine heatwaves (bleaching); harmful algal blooms (HABs); crown-of-thorns starfish (COTS) outbreaks; tropical cyclones; fishing pressure; tourism-related anchor damage; localised coastal development and desalination discharges.
Arabian (Persian) Gulf – Northeast	True reefs transitioning into marginal reef communities; structurally complex coral assemblages giving way to more stress-tolerant Gulf communities; relatively high coral diversity compared to the southern Gulf.	Extreme seasonal SST; elevated salinity; large tidal range and periodic aerial exposure; oceanic water exchange through the Strait of Hormuz.	Coastal development and habitat loss; Harmful Algal Blooms (HABs); oil and wastewater pollution; tourism-related anchor damage.
Arabian (Persian) Gulf – Inner	True framework-building reefs on offshore islands together with extensive marginal coastal reef systems; diverse coral assemblages adapted to extreme environmental conditions; high bioerosion rates; important commercial grouper habitats.	Hypersalinity; extreme seasonal temperature variability; restricted circulation; strong environmental gradients associated with the Shatt al Arab.	Marine heatwaves and mass bleaching; reduced freshwater and sediment discharge from Shatt al Arab; desalination effluent; industrial pollution; intensive fishing and abandoned fishing gear; physical damage from anchoring by recreational vessels.
Arabian (Persian) Gulf – Southeast	Predominantly marginal reefs with localised offshore framework-building reefs; stress-tolerant massive corals (<i>Porites</i> , <i>Platygyra</i> and <i>Dipsastraea</i>); remnant <i>Acropora</i> on offshore reefs.	Summer SSTs exceeding 36°C; hypersalinity; high evaporation; Shamal winds.	Recurrent mass bleaching; extensive land reclamation and dredging, with associated sediment resuspension and elevated turbidity; thermal and brine discharge; fishing pressure and abandoned gear.

2.5. Definition of the collapsed state of the ecosystem

Ecosystem collapse represents the final stage of degradation. It occurs when an ecosystem's defining biotic, abiotic and structural features are lost or altered to the point that the ecosystem transforms into a different type or is completely lost. Collapse may occur locally, for example at an individual reef. However, an assessed coral reef ecoregion is classified as Collapsed only when it is virtually certain that these defining features have been lost from all occurrences within the ecoregion. Collapse is not necessarily irreversible, and recovery may remain possible if suitable environmental and ecological conditions are restored.

For the coral reefs of the RSA, collapse is defined by the loss of hard corals to levels at which key ecological functions, including positive carbonate accretion and habitat provision can no longer be maintained. Across the RSA, many reefs occur naturally as marginal or low-relief reef systems, and collapse therefore cannot be inferred solely from limited topographic relief or naturally modest coral diversity. Instead, collapse is reached when living coral assemblages and associated ecological functions are reduced to levels at which recovery following disturbance becomes highly unlikely and the ecosystem transitions to a persistent non-coral dominated state. Collapse may also occur through the permanent physical loss of reef habitat, for example where land

reclamation, dredging or coastal development completely remove the geomorphological structure that supports the ecosystem.

Under the Red List of Ecosystems framework, collapse in the RSA is considered to occur when any of the following primary thresholds are met:

- a) Complete loss of coral reef area;
- b) Hard coral cover falling to 5% or less, representing local loss of the characteristic biota and associated ecological function;
- c) A climatic regime in which severe bleaching events occur, on average, at least once every three years over a 30-year period, or in which three severe mortality events occur within any five-year window, leaving insufficient time for coral recovery.

Collapsed coral reefs are often characterized by a phase shift from coral dominance to high abundances of other benthic components. In the Arabian (Persian) Gulf, collapse is likely to manifest as low-relief communities dominated by cyanobacteria, sediment-laden algal turf, or seasonal overgrowth of fleshy macroalgae. In the Gulf of Oman, collapse may be expressed as rubble fields, heavily eroded hardgrounds, or benthic communities dominated by non-coral organisms. In the Western Arabian Sea ecoregions, collapse may involve persistent macroalgal dominance and sustained reduction in coral cover, recruitment and survival. Collapse is also expected to be accompanied by declines in the abundance and diversity of associated reef organisms, including altered fish community structure. Although these ecosystem states differ among ecoregions, several biotic indicators can provide evidence of severe functional degradation and can be used to assess increasing risk of ecosystem collapse, including:

1. An algal-to-coral cover ratio of 5:1 or greater, indicating a shift towards algal dominance;
2. Branching corals comprising 5% or less of total hard coral cover, representing the near-complete loss of this structurally important growth form;
3. Severe depletion of key fish groups (e.g., herbivores and piscivores) to levels well below historical baselines.

3. Criterion Assessment

Coral reefs in **six** ecoregions within the **ROPME Sea Area** were assessed using IUCN Red List of Ecosystems (RLE) Criteria A–D (Table 3). The following section briefly describes the approach used for each criterion, with the detailed methods presented in the Annex.

Criterion A — Decline in Distribution

Decline in distribution of coral reefs over the past 50 years was assessed using hard coral cover data as a proxy and was calculated as the proportion of assessed reef sites currently with 5% or less hard coral cover. This represents a conservative threshold relative to the approximate 10% estimated minimum threshold for net accretion (Perry et al. 2013). Coral reefs in each ecoregion were classified as Vulnerable if they experienced a 30–50% decline, Endangered if the decline was 50–80%, and Critically Endangered if the decline exceeded 80%. Ecoregions with declines of 27–30% were classified as Near Threatened, and all others were considered Least Concern.

Criterion B — Restricted Geographic Distribution

Criterion B assesses the extent of occurrence (EOO) and area of occupancy (AOO) of the current distribution of coral reefs. EOO is the total area within the outer limits of the ecosystem's distribution, while AOO is the area occupied by the ecosystem, measured as the number of 10 by 10 km grid cells, applying the standard 1% rule. Both were derived from the consolidated regional reef-extent layer, based on UNEP-WCMC data and additional regional spatial datasets and validated by regional experts. For both metrics, the thresholds from the RLE guidelines were applied to assess risk, and additional conditions on continuing decline were evaluated using threat and biotic data from Criteria C and D.

Criterion C — Environmental Degradation

Criterion C evaluates the degradation of the abiotic environment and the risk this poses to ecosystem persistence. Globally, the most pertinent threat to coral reefs is the increasing occurrence of extreme marine heatwave events that cause coral bleaching and mortality. Under Criterion C, we evaluated historical changes in frequency of marine heat waves over the past 50 years (subcriterion C1, 1975–2025), informed by observed Degree Heating Weeks (DHW) records from 1985 to 2025, and projected changes over the next 50 years (subcriterion C2, 2026–2075). For both periods, annual maximum DHW, a satellite-derived measure of accumulated heat stress, was used to identify years in which widespread bleaching or severe mortality events occurred. Two complementary pathways to ecosystem collapse were assessed: a chronic pathway, capturing the progressive degradation driven by the long-term effects of frequently recurring bleaching events. This was assessed using the average return interval between severe bleaching events over a 30-year period. The second approach is a pulse pathway, capturing acute collapse driven by the clustering of extreme high-mortality events within any 5-year window. For both C1 and C2, the relative severity of decline was calculated by comparing the magnitude of past and projected changes against initial conditions and thresholds for coral reef collapse. Collapse thresholds were set at one severe bleaching event every three years for the chronic pathway, and three severe mortality events within five years for the pulse pathway. For C2, analyses were conducted under three emissions scenarios (SSP2-4.5, SSP3-7.0, and SSP5-8.5), with SSP2-4.5 and SSP3-7.0 treated as the primary scenarios. Risk categories were assigned using the severity–extent matrix, based on the proportion of reef area within each ecoregion experiencing different levels of relative decline. The most severe risk status across both chronic and pulse approaches, and C1 and C2, was taken as the final risk status under Criterion C.

Criterion D — Disruption of Biotic Processes and Interactions

Criterion D assesses the disruption of biotic processes and interactions over the past 50 years using three indicators: hard coral cover, the algae-to-coral ratio and the relative abundance of branching corals. Severe depletion of key fish groups, including herbivores and piscivores, was recognised as a potential indicator of functional degradation but was not included in the Criterion D assessment because comparable historical and current data were unavailable across ecoregions. Historical baselines were derived from published data and long-term monitoring records, while current values were derived from in situ monitoring data. The branching coral ratio was calculated from standardised site-year cover estimates for *Acropora*, *Pocillopora* and *Stylophora*; full data-selection and processing methods are provided in Annex 1. For each reef site, the change in each indicator was measured relative to an estimated historical baseline for the ecoregion and

an indicator-specific collapse threshold, representing the point at which the associated ecosystem function or characteristic was considered effectively lost. The proportion of sites experiencing varying degrees of decline was then evaluated, and a risk matrix was used to determine the risk status for each indicator. Finally, a heuristic, stepwise approach across all indicators was applied to derive the overall risk status under Criterion D for each ecoregion.

Table 3. Methodology, parameters and collapse thresholds used to assess coral reefs ecosystems in ROPME Sea Area under the IUCN Red List of Ecosystem criteria.

Criterion	Subcriterion	Indicator(s)	Data Sources	Collapse Threshold(s)	Criterion Assessed? (Yes/No)	Comments
A Reduction in geographic distribution	A1 – (Past 50 years)	Proportion of assessed reef sites with current hard coral cover at or below the collapse threshold	Regional benthic monitoring data; expert assessed collapsed sites; regional reef-extent layers (including UNEP-WCMC)	Local collapse: hard coral cover $\leq 5\%$. Sensitivity thresholds of 1–10% were also evaluated. Risk categories were based on the proportion of assessed sites reaching the selected threshold: CR $\geq 80\%$, EN $\geq 50\%$, VU $\geq 30\%$ and NT $\geq 27\%$.	Yes	Hard coral cover used as a proxy because no consistent 50-year time series of mapped reef extent was unavailable.
B Restricted geographic distribution	B1 – Extent of Occurrence (EOO)	Extent of Occurrence (EOO) + evidence of continuing decline or ongoing threats	Consolidated regional reef-extent layer; regional spatial datasets; expert review	CR $\leq 2,000 \text{ km}^2$; EN $\leq 20,000 \text{ km}^2$; VU $\leq 50,000 \text{ km}^2$ + ongoing decline or threats	Yes	Calculated per ecoregion using minimum convex polygons
	B2 -- Area of Occupancy (AOO)	Area of Occupancy (AOO) + ongoing decline or number of threat defined locations	Consolidated regional reef-extent layer; 10×10 km AOO grid	CR ≤ 2 occupied cells; EN ≤ 20 cells; VU ≤ 50 cells + ongoing decline or threats	Yes	Grid cells containing less than 1% reef cover were excluded following the standard 1% rule
C	C1 – Environmental degradation (past 50 years)	Changes in the frequency of severe bleaching events over 30-year periods (chronic pathway) and clustering of severe mortality events within five-year windows (pulse pathway)	NOAA Coral Reef Watch 5-km observed DHW data for 1985–2025; published bleaching and mortality observations; expert review	Ecoregion-specific DHW thresholds identified severe bleaching and mortality events. Primary collapse thresholds were an average return interval of three years or less for severe bleaching events and three severe mortality events within any five-year window.	Yes	Reference period: 1850–present; long-term warming trend assessed. Sensitivity thresholds were one event every five years for the chronic pathway and two events within five years for the pulse pathway.
C	C2 – Projected future degradation (50 years)	Projected changes in the frequency of severe bleaching events over 30-year periods and clustering of severe mortality	Modelled daily DHW projections from Mellin et al. (2024) under SSP2-4.5, SSP3-7.0 and SSP5-8.5; published bleaching	The same chronic and pulse collapse thresholds used for C1 were applied, together with ecoregion-specific future DHW thresholds that accounted for possible acclimation,	Yes	The final C2 classification used the best-case combination of SSP2-4.5 and higher future DHW thresholds representing

Criterion	Subcriterion	Indicator(s)	Data Sources	Collapse Threshold(s)	Criterion Assessed? (Yes/No)	Comments
		events within five-year windows	evidence; expert review	adaptation and species filtering		potential coral adaptation
D	D1 – Disruption of biotic processes (past 50 years)	Hard coral cover; branching coral ratio; algae–coral ratio	Historical published records; long-term monitoring data; recent benthic monitoring conducted between 2020 and 2025 using point-intercept, line-intercept, video and photoquadrat methods	Collapse thresholds: hard coral cover ≤5%; branching coral ratio ≤0.05; algae-to-coral cover ratio ≥5:1, expressed in the analysis as algal cover/(algae + hard coral) ≥0.833	Yes	Relative declines were evaluated through 1,000 iterations incorporating uncertainty in historical baselines. Indicator results were combined using the stepwise aggregation method

4. Risk Status

Coral reef ecoregions of the ROPME Sea Area differed in their condition but converged on a common overall classification of Critically Endangered (Table 4). Because projected thermal stress under C2 strongly influenced the overall results, Table 4 also presents the risk based on past and present changes, defined as the highest category across subcriteria A1, B1, B2, C1 and D1. This comparison distinguishes differences in historical decline, current ecosystem condition and restricted geographic distribution among ecoregions but does not alter the formal overall classification, which includes C2. Based on these past and present changes, the highest risk category was Critically Endangered for three ecoregions, Endangered for two and Vulnerable for one. Under subcriterion C2, the risk associated with projected thermal stress was classified as Critically Endangered for five ecoregions. Western Arabian Sea – North was Not Evaluated under Criterion C and Data Deficient under Criterion D. Nevertheless, its overall classification was retained as Critically Endangered based on subcriterion B1 alone. Because B1 already produced the highest possible risk category, the unavailable functional assessments could not have increased its overall classification. No ecoregion was assessed as Least Concern across all criteria, highlighting the widespread and cumulative pressures facing regional reefs.

Table 4. Summary of the RLE assessment results for **ROPME Sea Area** coral reef ecoregions. Only subcriteria A1 and D1 were assessed under Criteria A and D, respectively. “Observed change” represents the risk of ecosystem collapse based on observed conditions and changes (Criteria A1, B, C1 and D1), excluding criteria based on future projections. .1. “Overall RLE Risk” represents the highest category across all assessed criteria, including C2 (projected heat stress from ocean warming over the next 50 years).

Coral reef ecoregion	Subcriteria						Observed Change	Overall RLE Risk
	A1	B1	B2	C1	C2	D1		
Western Arabian Sea – South	LC	EN	EN	NT	CR	DD	EN (B1, B2)	CR (C2)
Western Arabian Sea – North	LC	CR	EN	NE	NE	DD	CR (B1)	CR (B1)
Gulf of Oman	LC	LC	VU	VU	CR	EN	EN (D1)	CR (C2)

Coral reef ecoregion	Subcriteria						Observed Change	Overall RLE Risk
	A1	B1	B2	C1	C2	D1		
Arabian (Persian) Gulf – Northeast	LC	VU	VU	NT	CR	VU	VU (B1, B2 D1)	CR (C2)
Arabian (Persian) Gulf – Inner	EN	VU	VU	CR	CR	CR	CR (C1, D1)	CR (C1, C2, D1)
Arabian (Persian) Gulf – Southeast	EN	LC	LC	EN	CR	CR	CR (D1)	CR (C2, D1)

Criterion A: Reduction in Geographic Distribution

Of the six ecoregions assessed, two were classified under a threatened category (Endangered), having lost a significant area of coral reefs over the past 50 years (Table 5). The greatest estimated reductions occurred in the Arabian (Persian) Gulf – Inner and Arabian (Persian) Gulf – Southeast, where 50% or more of assessed reef sites were estimated to have fallen below critical hard coral cover threshold used to define collapse. These declines likely reflect the cumulative effects of recurrent marine heatwaves, coastal development, dredging, land reclamation and sedimentation. The remaining four ecoregions were assessed as Least Concern, and no ecoregion was classified as Data Deficient.

Table 5. Risk status of ROPME Sea Area coral reef ecoregions under Criterion A, based on the proportion of assessed reef sites with hard coral cover at or below the 5% collapse threshold, used as a proxy for reduction in coral reef distribution over the past 50 years.

Coral reef ecoregion	Percentage of assessed reef sites at or below the 5% hard coral cover threshold	Subcriterion A1 status
Western Arabian Sea – South	9%	LC
Western Arabian Sea – North	0%	LC
Gulf of Oman	3%	LC
Arabian (Persian) Gulf – Northeast	0%	LC
Arabian (Persian) Gulf – Inner	50%	EN
Arabian (Persian) Gulf – Southeast	68%	EN

Criterion B: Restricted Geographic Distribution

Criterion B revealed substantial variation in the geographic distribution of coral reefs across the RSA (Table 6). Western Arabian Sea – North had the most restricted distribution, with an EOO of 419 km² and an AOO of five occupied grid cells. It was classified as Critically Endangered under B1 and Endangered under B2, resulting in an overall Criterion B classification of Critically Endangered. The B1 assessment was supported by evidence of continuing threats and expert confidence that the mapped layer captures the principal reef areas. Western Arabian Sea–South was classified as Endangered under both B1 and B2. The Gulf of Oman and the Northeast and Inner Gulf ecoregions were classified as Vulnerable, while the more widely distributed Southeast Gulf was classified as Least Concern. The restricted distributions of the two Western Arabian Sea ecoregions increase the likelihood that individual threatening events could affect a substantial proportion of their reef ecosystems.

Table 6. Risk status of **ROPME Sea Area** coral reef ecoregions under Criterion B, based on geographic distribution measured as the Extent of Occurrence (EOO) and Area of Occupancy (AOO). AOO is reported as the number of occupied 10 x 10 grid cells.

Coral reef ecoregion	EOO (km ²)	Subcriterion status B1	AOO	Subcriterion status B2	Overall Criterion B
Western Arabian Sea – South	4,153	EN	9	EN	EN
Western Arabian Sea – North	419	CR	7	EN	CR
Gulf of Oman	80,604	LC	22	VU	VU
Arabian (Persian) Gulf – Northeast	43,783	VU	31	VU	VU
Arabian (Persian) Gulf – Inner	31,289	VU	30	VU	VU
Arabian (Persian) Gulf – Southeast	116,581	LC	148	LC	LC

Criterion C: Environmental Degradation

Criterion C assessed the risk of collapse associated with changes in thermal-stress regimes over two time frames. C1 considered past changes using an inferred historical baseline and observed DHW records from 1985–2025, while C2 considered the risk associated with projected changes in DHW over 2026–2075. Under C1, three ecoregions were classified in threatened categories, two as Near Threatened and one as Not Evaluated. For each ecoregion, the C1 classification represents the higher-risk primary result from the chronic and pulse thermal-stress pathways.

Under C2, the risk associated with projected thermal stress was classified as Critically Endangered for all five ecoregions for which suitable thermal-response thresholds were available, under SSP2-4.5, SSP3-7.0 and SSP5-8.5. Western Arabian Sea–North was Not Evaluated under both C1 and C2 because region-specific evidence linking DHW exposure to bleaching and mortality was insufficient to establish reliable thermal-stress thresholds. The final Criterion C classification corresponds to the higher risk category from C1 and C2; consequently, the C2 result determined the final Critically Endangered classification under Criterion C for the five evaluated ecoregions (Table 7).

Table 7. Risk status of **ROPME Sea Area** coral reef ecoregions under Criterion C, based on observed (C1) and projected (C2) changes in the frequency and clustering of severe thermal-stress events.

Coral reef ecoregion	Subcriterion C1 status	Subcriterion C2 status	Overall Criterion C
Western Arabian Sea – South	NT	CR	CR
Western Arabian Sea – North	NE	NE	NE
Gulf of Oman	VU	CR	CR
Arabian (Persian) Gulf – Northeast	NT	CR	CR
Arabian (Persian) Gulf – Inner	CR	CR	CR
Arabian (Persian) Gulf – Southeast	EN	CR	CR

Criterion D: Disruption of biotic processes or interactions

Criterion D was assessed for four of the six ecoregions (Table 8). The Arabian (Persian) Gulf Southeast and Inner were classified as Critically Endangered, the Gulf of Oman as Endangered, and the Arabian (Persian) Gulf – Northeast as Vulnerable. The two Western Arabian Sea

ecoregions (North and South) were classified as Data Deficient because insufficient historical baseline data were available to estimate long-term biotic change.

In the Arabian (Persian) Gulf – Northeast, hard coral cover was classified as Near Threatened, the branching coral ratio falling within the Vulnerable-Endangered range, and the algae–coral ratio as Least Concern. Most branching-coral iterations produced an Endangered result, but no single category reached the 80% threshold required for assignment. These results should be interpreted cautiously because the historical baselines were based on very few sites. In the Inner and Southeast Gulf, the hard coral cover indicator fell within the Endangered-Critically Endangered range because no single category occurred in at least 80% of the iterations. Both ecoregions were classified with the most frequent outcome, being CR (EN-CR) for the Inner Gulf and EN (EN-CR) for the Southeast Gulf. In the Inner Gulf, the algae–coral ratio was classified as Least Concern because values at the four current monitoring sites remained well below the collapse threshold. This result should not be interpreted as evidence of good overall reef condition, as hard coral cover at these sites was also low and degradation was more clearly reflected by declines in hard coral cover and branching corals. Across the assessed ecoregions, risk status was driven primarily by declines in these two indicators relative to historical conditions, with the greatest changes observed in the Inner and Southeast Gulf.

Table 8. Risk status of **ROPME Sea Area** coral reef ecoregions under Criterion D, based on estimated declines over the past 50 years in three biotic indicators: hard coral cover, branching coral ratio and algae–coral ratio. The overall Criterion D status was derived by integrating the results across all three indicators using the stepwise approach. Ranges in risk e.g. EN-CR, represents uncertainty in the outcomes, and the most likely category is presented (outside of the parentheses) in addition to the range.

Coral reef ecoregion	Hard coral cover	Branching coral ratio	Algae–coral ratio	Overall Criterion D
Western Arabian Sea – South	DD	DD	DD	DD*
Western Arabian Sea – North	DD	DD	DD	DD*
Gulf of Oman	VU	EN	NT	EN
Arabian (Persian) Gulf – Northeast	NT	EN (VU-EN)	LC	VU
Arabian (Persian) Gulf – Inner	CR (EN- CR)	EN	LC	CR
Arabian (Persian) Gulf – Southeast	EN (EN-CR)	CR	EN	CR

* *Western Arabian Sea – North and Western Arabian Sea – South were classified as Data Deficient because the limited historical baseline data were considered insufficient to support a robust Criterion D assessment*

5. Conclusion and recommendations

This assessment provides the first region-wide evaluation of the risk of collapse of coral reef ecosystems across the ROPME Sea Area under the IUCN Red List of Ecosystems framework. Ecosystem condition varies considerably among the six ecoregions. The Arabian (Persian) Gulf – Inner and Southeast ecoregions exhibit the strongest evidence of historical degradation, including substantial declines in hard coral cover and the proportion of branching corals, and were classified as Critically Endangered under Criterion D. In contrast, the Gulf of Oman and the Arabian (Persian) Gulf – Northeast retain comparatively better ecosystem condition despite

ongoing pressures, while the two Western Arabian Sea ecoregions remain Data Deficient for parts of the assessment due to limited historical information.

Despite these regional differences, projected changes give cause for significant concern. Under subcriterion C2, five ecoregions were classified as Critically Endangered because projected increases in marine heatwave frequency are expected to exceed the recovery capacity of reef-building corals. Western Arabian Sea – North was Not Evaluated under subcriterion C2 because insufficient region-specific evidence was available to establish robust collapse thresholds. Nevertheless, each of the six ecoregions was classified as Critically Endangered overall, with subcriterion C2 determining the overall category for five ecoregions, and Criterion B driving the classification of Western Arabian Sea – North because of its restricted geographic distribution. These findings indicate that, despite supporting some of the world's most heat-tolerant coral reefs, the RSA is projected to face a high risk of ecosystem collapse under continued climate warming. This projection is consistent with the recent GCRMN regional assessment, which documented increasingly frequent marine heatwaves and shortening recovery intervals across the region (Burt et al., 2026). Present-day risk, however, reflects different factors across the region, including historical degradation, restricted geographic distribution and, in some cases, limited ecological knowledge resulting from insufficient historical or spatial monitoring data.

Conservation efforts should, therefore, combine global action to address anthropogenic greenhouse gas emissions with targeted local management. Reducing local pressures such as coastal development, dredging, land reclamation, pollution and overfishing will be essential to maintain ecosystem resilience and maximise recovery capacity from future disturbances. Protection should prioritise reefs that retain relatively high ecological integrity and recovery potential, including framework-building reefs, and reef areas that may function as refugia or important larval sources (Bejarano et al., 2022; Bento et al., 2021). Conservation strategies should also include restoration of degraded reefs, prioritising approaches that promote resilient coral populations and enhance resistance to future climate change.

The assessment also identifies several priorities for future research and management. Long-term, standardised monitoring should be expanded, especially in understudied ecoregions, particularly the Western Arabian Sea, where limited historical or spatial data constrained the assessment. Improved understanding of reef connectivity, ecosystem recovery and reef distribution would strengthen future reassessments. Continued collaboration and data sharing among ROPME countries will strengthen regional monitoring and coordinated conservation actions. Periodic reassessment using improved monitoring data and updated climate projections will be essential for evaluating changes in risk, measuring the effectiveness of management actions, and supporting implementation of the Kuwait Regional Convention, relevant ROPME Sea Area regional coral reef conservation initiatives, and broader international commitments, including the Kunming-Montreal Global Biodiversity Framework.

6. References

Aeby, G. S., Howells, E., Work, T., Abrego, D., Williams, G. J., Wedding, L. M., Caldwell, J. M., Moritsch, M., & Burt, J. A. (2020). Localized outbreaks of coral disease on Arabian reefs

- are linked to extreme temperatures and environmental stressors. *Coral Reefs*, 39(3), 829–846. <https://doi.org/10.1007/s00338-020-01928-4>
- Al-Ghadban, A. N., & El-Sammak, A. (2005). Sources, distribution and composition of the suspended sediments, Kuwait Bay, Northern Arabian Gulf. *Journal of Arid Environments*, 60(4), 647–661. <https://doi.org/10.1016/j.jaridenv.2004.07.017>
- Al-Jufaili, S., Al-Jabri, M., Al-Baluchi, A., Baldwin, R. M., Wilson, S. C., West, F., & Matthews, A. D. (1999). Human Impacts on Coral Reefs in the Sultanate of Oman. *Estuarine, Coastal and Shelf Science*, 49, 65–74. [https://doi.org/10.1016/S0272-7714\(99\)80010-9](https://doi.org/10.1016/S0272-7714(99)80010-9)
- Al-Mansoori, N., McParland, D., Howells, E., Bauman, A., & Burt, J. A. (2020). Coral bioerosion on the marginal reefs of northeastern Arabia. *Aquatic Ecosystem Health & Management*, 23(2), 187–195. <https://doi.org/10.1080/14634988.2019.1677204>
- AlMealla, R. K., Edullantes, B., & Hepburn, L. J. (2024). Bleaching threatens positive carbonate budgets on Bahraini reefs. *Marine Biology*, 171(1), 39. <https://doi.org/10.1007/s00227-023-04351-9>
- Al-Mutairi, K. A. (2025). ANTHROPOCENE IMPRINTS ON THE PERSIAN GULF (ARABIAN GULF): A COMPREHENSIVE REVIEW OF POLLUTION AND CONSERVATION CHALLENGES. *Applied Ecology and Environmental Research*, 23(5), 9167–9196. https://doi.org/10.15666/aeer/2305_91679196
- Baker, A. C., Glynn, P. W., & Riegl, B. (2008). Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook. *Estuarine, Coastal and Shelf Science*, 80(4), 435–471. <https://doi.org/10.1016/j.ecss.2008.09.003>
- Basson, P. W., & Bobrowski, L. (1977). Biotopes of the Western Arabian Gulf: Marine Life and Environments of Saudi Arabia. Dhahran, Saudi Arabia : Aramco Dept. of Loss Prevention and Environmental Affairs.
- Bauman, A., Baird, A., Burt, J., Pratchett, M., & Feary, D. (2014). Patterns of coral settlement in an extreme environment: The southern Persian Gulf (Dubai, United Arab Emirates). *Marine Ecology Progress Series*, 499, 115–126. <https://doi.org/10.3354/meps10662>
- Bauman, A. G., Burt, J. A., Feary, D. A., Marquis, E., & Usseglio, P. (2010). Tropical harmful algal blooms: An emerging threat to coral reef communities? *Marine Pollution Bulletin*, 60(11), 2117–2122. <https://doi.org/10.1016/j.marpolbul.2010.08.015>
- Bejarano, I., Orenes-Salazar, V., Bento, R., García-Charton, J. A., & Mateos-Molina, D. (2022). Coral reefs at Sir Bu Nair Island: An offshore refuge of *Acropora* in the southern Arabian Gulf. *Marine Pollution Bulletin*, 178, 113570. <https://doi.org/10.1016/j.marpolbul.2022.113570>
- Bejarano, I., Orenes-Salazar, V., Pittman, S. J., García-Charton, J. A., & Mateos-Molina, D. (2025). Coral reef fish assemblages of protected remnant *Acropora* reefs in the Southern Arabian Gulf. *Regional Studies in Marine Science*, 92, 104592. <https://doi.org/10.1016/j.rsma.2025.104592>
- Ben-Romdhane, H., Al-Musallami, M., Marpu, P. R., Ouarda, T. B. M. J., & Ghedira, H. (2018). Change detection using remote sensing in a reef environment of the UAE during the extreme event of El Niño 2015–2016. *International Journal of Remote Sensing*, 39(19), 6358–6382. <https://doi.org/10.1080/01431161.2018.1460502>

- Bento, R., Cavalcante, G., Mateos-Molina, D., Riegl, B., & Bejarano, I. (2021). Recruitment and larval connectivity of a remnant *Acropora* community in the Arabian Gulf, United Arab Emirates. *Coral Reefs*, 40(6), 1889–1898. <https://doi.org/10.1007/s00338-021-02187-7>
- Bento, R., Feary, D. A., Hoey, A. S., & Burt, J. A. (2017). Settlement Patterns of Corals and other Benthos on Reefs with Divergent Environments and Disturbances Histories around the Northeastern Arabian Peninsula. *Frontiers in Marine Science*, 4, 305. <https://doi.org/10.3389/fmars.2017.00305>
- Beyer, H. L., Kennedy, E. V., Begger, M., Chen, C. A., Cinner, J. E., Darling, E. S., Eakin, C. M., Gates, R. D., Heron, S. F., Knowlton, N., Obura, D. O., Palumbi, S. R., Possingham, H. P., Puotinen, M., Runtz, R. K., Skirving, W. J., Spalding, M., Wilson, K. A., Wood, S., ... Hoegh-Guldberg, O. (2018). Risk-sensitive planning for conserving coral reefs under rapid climate change. *Conservation Letters*, 11(6), e12587. <https://doi.org/10.1111/conl.12587>
- Biophysical model of coral population connectivity in the Arabian/Persian Gulf. (2020). In *Advances in Marine Biology* (Vol. 87, pp. 193–221). Elsevier. <https://doi.org/10.1016/bs.amb.2020.07.001>
- Bland, L. M., Keith, D. A., Miller, R. M., Murray, N. J., & Rodríguez, J. P. (2017). Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria, version 1.1. International Union for the Conservation of Nature, Gland, Switzerland.
- Bozec, Y. -M., Adam, A. A. S., Nava, B. A., Cresswell, A. K., Haller-Bull, V., Iwanaga, T., Lachs, L., Matthews, S. A., McWhorter, J. K., Anthony, K. R. N., Condie, S. A., Halloran, P. R., Ortiz, J. -C., Riginos, C., & Mumby, P. J. (2025). A rapidly closing window for coral persistence under global warming. *Ecology*. <https://doi.org/10.1101/2025.01.23.634487>
- Brandl, S. J., Johansen, J. L., Casey, J. M., Tornabene, L., Morais, R. A., & Burt, J. A. (2020). Extreme environmental conditions reduce coral reef fish biodiversity and productivity. *Nature Communications*, 11(1), 3832. <https://doi.org/10.1038/s41467-020-17731-2>
- Briggs, N. D., Page, C. A., Giuliano, C., Alessi, C., Hoogenboom, M., Bay, L. K., & Randall, C. J. (2024). Dissecting coral recovery: Bleaching reduces reproductive output in *Acropora millepora*. *Coral Reefs*, 43(3), 557–569. <https://doi.org/10.1007/s00338-024-02483-y>
- Burt, J. (2015). Arabian Gulf reef fishes: A valuable but vulnerable asset for climate change research. *Qscience Proceedings*, 2015(5), 9. <https://doi.org/10.5339/qproc.2015.qulss2015.9>
- Burt, J. A. (2014). The environmental costs of coastal urbanization in the Arabian Gulf. *City*, 18(6), 760–770. <https://doi.org/10.1080/13604813.2014.962889>
- Burt, J. A. (2024). Coral Reefs of the Emirates. In J. A. Burt (Ed.), *A Natural History of the Emirates* (pp. 325–351). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-37397-8_11
- Burt, J. A., & Bauman, A. G. (2020). Suppressed coral settlement following mass bleaching in the southern Persian/Arabian Gulf. *Aquatic Ecosystem Health & Management*, 23(2), 166–174. <https://doi.org/10.1080/14634988.2019.1676024>
- Burt, J. A., Bento, R. C., Al Harthi, S., & AlMealla, R. K. (2026). Chapter 8–ROPME Sea area. In González-Rivero, M., et al. *Status of Coral Reefs of the World: 2025*. Global Coral Reef Monitoring Network and International Coral Reef Initiative, 2.

- Burt, J. A., Coles, S., Van Lavieren, H., Taylor, O., Looker, E., & Samimi-Namin, K. (2016). Oman's coral reefs: A unique ecosystem challenged by natural and man-related stresses and in need of conservation. *Marine Pollution Bulletin*, 105(2), 498–506.
<https://doi.org/10.1016/j.marpolbul.2015.11.010>
- Burt, J. A., Feary, D. A., Bauman, A. G., Usseglio, P., Cavalcante, G. H., & Sale, P. F. (2011). Biogeographic patterns of reef fish community structure in the northeastern Arabian Peninsula. *ICES Journal of Marine Science*, 68(9), 1875–1883.
<https://doi.org/10.1093/icesjms/fsr129>
- Burt, J. A., & Paparella, F. (2024). The Marine Environment of the Emirates. In J. A. Burt (Ed.), *A Natural History of the Emirates* (pp. 95–117). Springer Nature Switzerland.
https://doi.org/10.1007/978-3-031-37397-8_4
- Burt, J., Al-Harthi, S., & Al-Cibahy, A. (2011). Long-term impacts of coral bleaching events on the world's warmest reefs. *Marine Environmental Research*, 72(4), 225–229.
<https://doi.org/10.1016/j.marenvres.2011.08.005>
- Byrne, M., Clements, M., Kingsford, M., Foo, S. A., Ramjus, N., & Waller, A. (2025). Marine heatwave-driven mortality of bleached colonies of the massive coral *Goniopora* is exacerbated by a black band disease epizootic.
- Cavalcante, G. H., Feary, D. A., & Burt, J. A. (2016). The influence of extreme winds on coastal oceanography and its implications for coral population connectivity in the southern Arabian Gulf. *Marine Pollution Bulletin*, 105(2), 489–497.
<https://doi.org/10.1016/j.marpolbul.2015.10.031>
- Cheng, L., Trenberth, K. E., Fasullo, J., Boyer, T., Abraham, J., & Zhu, J. (2017). Improved estimates of ocean heat content from 1960 to 2015. *Science Advances*, 3(3), e1601545.
<https://doi.org/10.1126/sciadv.1601545>
- Claereboudt, M. R. (2019). Oman. In *World Seas: An Environmental Evaluation* (pp. 25–47). Elsevier. <https://doi.org/10.1016/B978-0-08-100853-9.00002-6>
- Claereboudt, M. R., & Bruss, G. (2025). Short distances dominate connectivity patterns of coral communities in the North-West Arabian Sea. *Frontiers in Marine Science*, 11, 1494563.
<https://doi.org/10.3389/fmars.2024.1494563>
- Coles, S. L. (2003). Coral species diversity and environmental factors in the Arabian Gulf and the Gulf of Oman: A comparison to the Indo-Pacific Region. *Atoll Research Bulletin*, 507, 1–19.
<https://doi.org/10.5479/si.00775630.507.1>
- Cróquer, A., & Weil, E. (2009). Changes in Caribbean coral disease prevalence after the 2005 bleaching event. *Diseases of Aquatic Organisms*, 87, 33–43.
<https://doi.org/10.3354/dao02164>
- De Clippele, L. H., Díaz, L. A., Andradi-Brown, D. A., Lazuardi, M. E., Iqbal, M., Zainudin, I. M., Prabuning, D., Van Hooideonk, R., Hakim, A., Agung, F., Dermawan, A., & Hennige, S. J. (2023). Evaluating annual severe coral bleaching risk for marine protected areas across Indonesia. *Marine Policy*, 148, 105428. <https://doi.org/10.1016/j.marpol.2022.105428>
- DeCarlo, T. M., & Whitaker, H. V. (2025). Coral Bleaching Projections for the Great Barrier Reef Throughout the 21st Century. *Geophysical Research Letters*, 52(23), e2025GL119834.
<https://doi.org/10.1029/2025GL119834>

- Donner, S. D., Rickbeil, G. J. M., & Heron, S. F. (2017). A new, high-resolution global mass coral bleaching database. *PLOS ONE*, 12(4), e0175490.
<https://doi.org/10.1371/journal.pone.0175490>
- Eakin, C. M., Heron, S. F., Connolly, S. R., Devotta, D. A., Liu, G., Geiger, E. F., De La Cour, J. L., Gomez, A. M., Skirving, W. J., Baird, A. H., Cantin, N. E., Couch, C. S., Donner, S. D., Gilmour, J., Gonzalez-Rivero, M., Gudka, M., Harrison, H. B., Hodgson, G., Hoegh-Guldberg, O., ... Manzello, D. P. (2026). Severe and widespread coral reef damage during the 2014-2017 Global Coral Bleaching Event. *Nature Communications*, 17(1), 1318.
<https://doi.org/10.1038/s41467-025-67506-w>
- Elma, E., Gullström, M., Yahya, S. A. S., Jouffray, J. -B., East, H. K., & Nyström, M. (2023). Post-bleaching alterations in coral reef communities. *Marine Pollution Bulletin*, 186, 114479.
<https://doi.org/10.1016/j.marpolbul.2022.114479>
- Emslie, M. J., Logan, M., Bray, P., Ceccarelli, D. M., Cheal, A. J., Hughes, T. P., Johns, K. A., Jonker, M. J., Kennedy, E. V., Kerry, J. T., Mellin, C., Miller, I. R., Osborne, K., Puotinen, M., Sinclair-Taylor, T., & Sweatman, H. (2024). Increasing disturbance frequency undermines coral reef recovery. *Ecological Monographs*, 94(3), e1619. <https://doi.org/10.1002/ecm.1619>
- Erpenbeck, D., Gholami, A., Hesni, M. A., Ranjbar, M. S., Galitz, A., Eickhoff, B., Namuth, L., Schumacher, T., Esmaili, H. R., Wörheide, G., & Teimori, A. (2020). Molecular biodiversity of Iranian shallow water sponges. *Systematics and Biodiversity*, 18(2), 192–202.
<https://doi.org/10.1080/14772000.2020.1737978>
- Erpenbeck, D., Voigt, O., Al-Aidaros, A. M., Berumen, M. L., Büttner, G., Catania, D., Guirguis, A. N., Paulay, G., Schätzle, S., & Wörheide, G. (2016). Molecular biodiversity of Red Sea demosponges. *Marine Pollution Bulletin*, 105(2), 507–514.
<https://doi.org/10.1016/j.marpolbul.2015.12.004>
- Feary, D. A., Burt, J. A., Bauman, A. G., Usseglio, P., Sale, P. F., & Cavalcante, G. H. (2010). Fish communities on the world's warmest reefs: What can they tell us about the effects of climate change in the future? *Journal of Fish Biology*, 77(8), 1931–1947.
<https://doi.org/10.1111/j.1095-8649.2010.02777.x>
- Feary, D. A., Burt, J. A., Cavalcante, G. H., & Bauman, A. G. (2012). Extreme Physical Factors and the Structure of Gulf Fish and Reef Communities. In B. M. Riegl & S. J. Purkis (Eds.), *Coral Reefs of the Gulf* (Vol. 3, pp. 163–170). Springer Netherlands. https://doi.org/10.1007/978-94-007-3008-3_9
- Foster, K., Foster, G., Al-Cibahy, A. S., Al-Harthi, S., Purkis, S. J., & Riegl, B. M. (2012). Environmental Setting and Temporal Trends in Southeastern Gulf Coral Communities. In B. M. Riegl & S. J. Purkis (Eds.), *Coral Reefs of the Gulf* (Vol. 3, pp. 51–70). Springer Netherlands. https://doi.org/10.1007/978-94-007-3008-3_4
- Gilmour, J. P., Smith, L. D., Heyward, A. J., Baird, A. H., & Pratchett, M. S. (2013). Recovery of an Isolated Coral Reef System Following Severe Disturbance. *Science*, 340(6128), 69–71.
<https://doi.org/10.1126/science.1232310>
- Glynn, P. W. (1993). Monsoonal upwelling and episodic *Acanthaster* predation as probable controls of coral reef distribution and community structure in Oman, Indian Ocean.

- Graham, N. A. J., Nash, K. L., & Kool, J. T. (2011). Coral reef recovery dynamics in a changing world. *Coral Reefs*, 30(2), 283–294. <https://doi.org/10.1007/s00338-010-0717-z>
- Grandcourt, E. (2012). Reef Fish and Fisheries in the Gulf. In B. M. Riegl & S. J. Purkis (Eds.), *Coral Reefs of the Gulf* (Vol. 3, pp. 127–161). Springer Netherlands. https://doi.org/10.1007/978-94-007-3008-3_8
- Guest, J. R., Edmunds, P. J., Gates, R. D., Kuffner, I. B., Andersson, A. J., Barnes, B. B., Chollett, I., Courtney, T. A., Elahi, R., Gross, K., Lenz, E. A., Mitarai, S., Mumby, P. J., Nelson, H. R., Parker, B. A., Putnam, H. M., Rogers, C. S., & Toth, L. T. (2018). A framework for identifying and characterising coral reef “oases” against a backdrop of degradation. *Journal of Applied Ecology*, 55(6), 2865–2875. <https://doi.org/10.1111/1365-2664.13179>
- Hadj-Hammou, J., Bartholomew, A., Bento, R. C., Mohamed, F. A., Cavalcante, G. H., & Burt, J. A. (2025). Bleaching Impacts on the Last Remaining Acropora-dominated Reefs in the United Arab Emirates. *Diversity*, 17(9), 610. <https://doi.org/10.3390/d17090610>
- Henley, B. J., McGregor, H. V., King, A. D., Hoegh-Guldberg, O., Arzey, A. K., Karoly, D. J., Lough, J. M., DeCarlo, T. M., & Linsley, B. K. (2024). Highest ocean heat in four centuries places Great Barrier Reef in danger. *Nature*, 632(8024), 320–326. <https://doi.org/10.1038/s41586-024-07672-x>
- Heron, S. F., Johnston, L., Liu, G., Geiger, E., Maynard, J., De La Cour, J., Johnson, S., Okano, R., Benavente, D., Burgess, T., Iguel, J., Perez, D., Skirving, W., Strong, A., Tirak, K., & Eakin, C. (2016). Validation of Reef-Scale Thermal Stress Satellite Products for Coral Bleaching Monitoring. *Remote Sensing*, 8(1), 59. <https://doi.org/10.3390/rs8010059>
- Heron, S. F., Maynard, J. A., Van Hooidek, R., & Eakin, C. M. (2016). Warming Trends and Bleaching Stress of the World’s Coral Reefs 1985–2012. *Scientific Reports*, 6(1), 38402. <https://doi.org/10.1038/srep38402>
- Hoegh-Guldberg, O. (1999). Climate change, coral bleaching and the future of the world’s coral reefs. *Marine and Freshwater Research*, 50(8), 839–866. <https://doi.org/10.1071/MF99078>
- Hoey, A. S., Feary, D. A., Burt, J. A., Vaughan, G., Pratchett, M. S., & Berumen, M. L. (2016). Regional variation in the structure and function of parrotfishes on Arabian reefs. *Marine Pollution Bulletin*, 105(2), 524–531. <https://doi.org/10.1016/j.marpolbul.2015.11.035>
- Howells, E. J., Vaughan, G. O., Work, T. M., Burt, J. A., & Abrego, D. (2020). Annual outbreaks of coral disease coincide with extreme seasonal warming. *Coral Reefs*, 39(3), 771–781. <https://doi.org/10.1007/s00338-020-01946-2>
- Hughes, T. P., Anderson, K. D., Connolly, S. R., Heron, S. F., Kerry, J. T., Lough, J. M., Baird, A. H., Baum, J. K., Berumen, M. L., Bridge, T. C., Claar, D. C., Eakin, C. M., Gilmour, J. P., Graham, N. A. J., Harrison, H., Hobbs, J. -P. A., Hoey, A. S., Hoogenboom, M., Lowe, R. J., ... Wilson, S. K. (2018). Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. *Science*, 359(6371), 80–83. <https://doi.org/10.1126/science.aan8048>
- Ismail, K. A., & Al Shehhi, M. R. (2022). Upwelling and nutrient dynamics in the Arabian Gulf and sea of Oman. *PLOS ONE*, 17(10), e0276260. <https://doi.org/10.1371/journal.pone.0276260>
- Jabado, R. W., Antonopoulou, M., Möller, M., Al Suweidi, A. S., Al Suwaidi, A. M. S., & Mateos-Molina, D. (2021). Baited Remote Underwater Video Surveys to assess relative abundance

- of sharks and rays in a long standing and remote marine protected area in the Arabian Gulf. *Journal of Experimental Marine Biology and Ecology*, 540, 151565.
<https://doi.org/10.1016/j.jembe.2021.151565>
- Johns, W. E., Yao, F., Olson, D. B., Josey, S. A., Grist, J. P., & Smeed, D. A. (2003). Observations of seasonal exchange through the Straits of Hormuz and the inferred heat and freshwater budgets of the Persian Gulf. *Journal of Geophysical Research: Oceans*, 108(C12), 2003JC001881. <https://doi.org/10.1029/2003JC001881>
- Kavousi, J., Tavakoli-Kolour, P., Mohammadizadeh, M., Bahrami, A., & Barkhordari, A. (2014). Mass coral bleaching in the northern Persian Gulf, 2012. *Scientia Marina*, 78(3), 397–404.
<https://doi.org/10.3989/scimar.03914.16A>
- Keith, D., Ferrer-Paris, J. R., Ghoraba, S. M. M., Henriksen, S., Monyeki, M., Murray, N., Nicholson, E., Rowland, J., Skowno, A., & Slingsby, J. A. (2024). Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria: Version 2.0. IUCN.
- Kembrey, H., Pittman, S. J., Bejarano, I., Blanco-Parra, M. D. P., Jabado, R. W., Yaghmour, F., & Mateos-Molina, D. (2024). Fish–Seascape Associations Within an Offshore Protected Area in the Arabian Gulf. *Marine Ecology*, 45(6), e12847. <https://doi.org/10.1111/maec.12847>
- Levitan, D., Boudreau, W., Jara, J., & Knowlton, N. (2014). Long-term reduced spawning in *Orbicella* coral species due to temperature stress. *Marine Ecology Progress Series*, 515, 1–10. <https://doi.org/10.3354/meps11063>
- Lin, Y. -J., Rabaoui, L., Basali, A. U., Lopez, M., Lindo, R., Krishnakumar, P. K., Qurban, M. A., Prihartato, P. K., Cortes, D. L., Qasem, A., Al-Abdulkader, K., & Roa-Ureta, R. H. (2021). Long-term ecological changes in fishes and macro-invertebrates in the world's warmest coral reefs. *Science of The Total Environment*, 750, 142254.
<https://doi.org/10.1016/j.scitotenv.2020.142254>
- Lin, Y. -J., Roa-Ureta, R. H., Premlal, P., Nazeer, Z., Pulikkoden, A. R. K., Qurban, M. A., Prihartato, P. K., Alghamdi, H. A., Qasem, A. M., & Rabaoui, L. (2022). Habitat-forming organisms in the offshore seabed of the western Arabian Gulf. *Regional Studies in Marine Science*, 53, 102446. <https://doi.org/10.1016/j.rsma.2022.102446>
- Liu, G., Eakin, C. M., Rauenzahn, J. L., & Christensen, T. R. L. (2012). NOAA Coral Reef Watch's Decision Support System for Coral Reef Management.
- Liu, G., Strong, A. E., Skirving, W., & Arzayus, L. F. (2005). Overview of NOAA Coral Reef Watch Program's Near-Real-Time Satellite Global Coral Bleaching Monitoring Activities.
- Mateos-Molina, D., Antonopoulou, M., Baldwin, R., Bejarano, I., Burt, J. A., García-Charton, J. A., Al-Ghais, S. M., Walgamage, J., & Taylor, O. J. S. (2020). Applying an integrated approach to coastal marine habitat mapping in the north-western United Arab Emirates. *Marine Environmental Research*, 161, 105095. <https://doi.org/10.1016/j.marenvres.2020.105095>
- Mellin, C., Brown, S., Cantin, N., Klein-Salas, E., Mouillot, D., Heron, S. F., & Fordham, D. A. (2024). Cumulative risk of future bleaching for the world's coral reefs. *Science Advances*, 10(26), eadn9660. <https://doi.org/10.1126/sciadv.adn9660>
- Mendonça, V. M., Jabri, M. M. A., Ajmi, I. A., Al, M., Areimi, M. A., & Aghbari, H. A. A. (2010). Persistent and Expanding Population Outbreaks of the Corallivorous Starfish *Acanthaster planci* in the Northwestern Indian Ocean: Are They Really a Consequence of

- Unsustainable Starfish Predator Removal through Overfishing in Coral Reefs, or a Response to a Changing Environment? *Zoological Studies*, 49(1), 108–123.
- Merchant, C. J., Allan, R. P., & Embury, O. (2025). Quantifying the acceleration of multidecadal global sea surface warming driven by Earth's energy imbalance. *Environmental Research Letters*, 20(2), 024037. <https://doi.org/10.1088/1748-9326/adaa8a>
- Moradi, M., Malekzadeh-Viayeh, R., & Eshaghi-Rad, J. (2014). Biodiversity of scleractinian corals in the reefs of Qeshm and Larak Islands of the Persian Gulf, in association with environmental variables. *Journal of the Marine Biological Association of the United Kingdom*, 94(5), 907–916. <https://doi.org/10.1017/S0025315414000411>
- Mudge, L., & Bruno, J. F. (2023). Disturbance intensification is altering the trait composition of Caribbean reefs, locking them into a low functioning state. *Scientific Reports*, 13(1), 14022. <https://doi.org/10.1038/s41598-023-40672-x>
- Obura, D., Gudka, M., Samoilys, M., Osuka, K., Mbugua, J., Keith, D. A., Porter, S., Roche, R., Van Hooidek, R., Ahamada, S., Araman, A., Karisa, J., Komakoma, J., Madi, M., Ravinia, I., Razafindrainibe, H., Yahya, S., & Zivane, F. (2022). Vulnerability to collapse of coral reef ecosystems in the Western Indian Ocean. *Nature Sustainability*, 5(2), 104–113. <https://doi.org/10.1038/s41893-021-00817-0>
- Oh, D., Cresswell, A. K., Thomson, D. P., & Renton, M. (2025). Do greater coral cover and morphological diversity increase habitat complexity? *Coral Reefs*, 44(1), 257–272. <https://doi.org/10.1007/s00338-024-02602-9>
- Oladi, M., & Shokri, M. R. (2021). Multiple benthic indicators are efficient for health assessment of coral reefs subjected to petroleum hydrocarbons contamination: A case study in the Persian Gulf. *Journal of Hazardous Materials*, 409, 124993. <https://doi.org/10.1016/j.jhazmat.2020.124993>
- Perry, C. T., Murphy, G. N., Kench, P. S., Smithers, S. G., Edinger, E. N., Steneck, R. S., & Mumby, P. J. (2013). Caribbean-wide decline in carbonate production threatens coral reef growth. *Nature Communications*, 4(1), 1402. <https://doi.org/10.1038/ncomms2409>
- Pilcher, N. J., Antonopoulou, M., Perry, L., Abdel-Moati, M. A., Al Abdessalaam, T. Z., Albeldawi, M., Al Ansi, M., Al-Mohannadi, S. F., Al Zahlawi, N., Baldwin, R., Chikhi, A., Das, H. S., Hamza, S., Kerr, O. J., Al Kiyumi, A., Mobaraki, A., Al Suwaidi, H. S., Al Suweidi, A. S., Sawaf, M., ... Willson, A. (2014). Identification of Important Sea Turtle Areas (ITAs) for hawksbill turtles in the Arabian Region. *Journal of Experimental Marine Biology and Ecology*, 460, 89–99. <https://doi.org/10.1016/j.jembe.2014.06.009>
- Pratchett, M. S., Baird, A. H., Bauman, A. G., & Burt, J. A. (2017). Abundance and composition of juvenile corals reveals divergent trajectories for coral assemblages across the United Arab Emirates. *Marine Pollution Bulletin*, 114(2), 1031–1035. <https://doi.org/10.1016/j.marpolbul.2016.11.036>
- Pratchett, M. S., Heron, S. F., Mellin, C., & Cumming, G. S. (2021). Recurrent Mass-Bleaching and the Potential for Ecosystem Collapse on Australia's Great Barrier Reef. In J. G. Canadell & R. B. Jackson (Eds.), *Ecosystem Collapse and Climate Change* (Vol. 241, pp. 265–289). Springer International Publishing. https://doi.org/10.1007/978-3-030-71330-0_10

- Pratchett, M. S., McCowan, D., Maynard, J. A., & Heron, S. F. (2013). Changes in Bleaching Susceptibility among Corals Subject to Ocean Warming and Recurrent Bleaching in Moorea, French Polynesia. *PLoS ONE*, 8(7), e70443. <https://doi.org/10.1371/journal.pone.0070443>
- Purkis, S., & Riegl, B. (2005). Spatial and temporal dynamics of Arabian Gulf coral assemblages quantified from remote-sensing and in situ monitoring data. *Marine Ecology Progress Series*, 287, 99–113. <https://doi.org/10.3354/meps287099>
- Randall, J. E. (1995). *Coastal fishes of Oman*. University of Hawaii Press.
- Rezai, H., Wilson, S., Claereboudt, M., & Riegl, B. (2004). Coral reef status in the ROPME sea area: Arabian/Persian Gulf, Gulf of Oman and Arabian Sea. *Status of Coral Reefs of the World*, 1, 155–170.
- Richlen, M. L., Morton, S. L., Jamali, E. A., Rajan, A., & Anderson, D. M. (2010). The catastrophic 2008–2009 red tide in the Arabian gulf region, with observations on the identification and phylogeny of the fish-killing dinoflagellate *Cochlodinium polykrikoides*. *Harmful Algae*, 9(2), 163–172. <https://doi.org/10.1016/j.hal.2009.08.013>
- Riegl, B. (2002). Effects of the 1996 and 1998 positive sea-surface temperature anomalies on corals, coral diseases and fish in the Arabian Gulf (Dubai, UAE). *Marine Biology*, 140(1), 29–40. <https://doi.org/10.1007/s002270100676>
- Riegl, B., Johnston, M., Purkis, S., Howells, E., Burt, J., Steiner, S. C. C., Sheppard, C. R. C., & Bauman, A. (2018). Population collapse dynamics in *Acropora downingi*, an Arabian/Persian Gulf ecosystem-engineering coral, linked to rising temperature. *Global Change Biology*, 24(6), 2447–2462. <https://doi.org/10.1111/gcb.14114>
- Riegl, B. M., & Purkis, S. J. (2012). Environmental Constraints for Reef Building in the Gulf. In B. M. Riegl & S. J. Purkis (Eds.), *Coral Reefs of the Gulf* (Vol. 3, pp. 5–32). Springer Netherlands. https://doi.org/10.1007/978-94-007-3008-3_2
- Robinson, J. P. W., Wilson, S. K., & Graham, N. A. J. (2019). Abiotic and biotic controls on coral recovery 16 years after mass bleaching. *Coral Reefs*, 38(6), 1255–1265. <https://doi.org/10.1007/s00338-019-01831-7>
- Salm, R. V. (1993). Coral reefs of the Sultanate of Oman. *Atoll Research Bulletin*, 380.
- Samimi-Namin, K., & Van Ofwegen, L. (2012). The Octocoral Fauna of the Gulf. In B. M. Riegl & S. J. Purkis (Eds.), *Coral Reefs of the Gulf* (Vol. 3, pp. 225–252). Springer Netherlands. https://doi.org/10.1007/978-94-007-3008-3_12
- Sarofim, M. C., Smith, C. J., Malek, P., McDuffie, E. E., Hartin, C. A., Lay, C. R., & McGrath, S. (2024). High radiative forcing climate scenario relevance analyzed with a ten-million-member ensemble. *Nature Communications*, 15(1), 8185. <https://doi.org/10.1038/s41467-024-52437-9>
- Seveso, D., Stahl, J. H., & Landes, A. (2024). An outbreak of *Acanthaster* spp. In the Gulf of Oman (United Arab Emirates). *Marine Biodiversity*, 54(4), 62. <https://doi.org/10.1007/s12526-024-01456-2>
- Sheppard, C., Al-Husiani, M., Al-Jamali, F., Al-Yamani, F., Baldwin, R., Bishop, J., Benzoni, F., Dutrieux, E., Dulvy, N. K., Durvasula, S. R. V., Jones, D. A., Loughland, R., Medio, D., Nithyanandan, M., Pilling, G. M., Polikarpov, I., Price, A. R. G., Purkis, S. J., Riegl, B. M., ...

- Zainal, K. (2012). Environmental Concerns for the Future of Gulf Coral Reefs. In B. M. Riegl & S. J. Purkis (Eds.), *Coral Reefs of the Gulf* (Vol. 3, pp. 349–373). Springer Netherlands. https://doi.org/10.1007/978-94-007-3008-3_16
- Sheppard, C., Al-Husiani, M., Al-Jamali, F., Al-Yamani, F., Baldwin, R., Bishop, J., Benzoni, F., Dutrieux, E., Dulvy, N. K., Durvasula, S. R. V., Jones, D. A., Loughland, R., Medio, D., Nithyanandan, M., Pilling, G. M., Polikarpov, I., Price, A. R. G., Purkis, S., Riegl, B., ... Zainal, K. (2010). The Gulf: A young sea in decline. *Marine Pollution Bulletin*, 60(1), 13–38. <https://doi.org/10.1016/j.marpolbul.2009.10.017>
- Sheppard, C., & Loughland, R. (2002). Coral mortality and recovery in response to increasing temperature in the southern Arabian Gulf. *Aquatic Ecosystem Health & Management*, 5(4), 395–402. <https://doi.org/10.1080/14634980290002020>
- Sheppard, C. R. C., & Salm, R. V. (1988). Reef and coral communities of Oman, with a description of a new coral species (Order Scleractinia, genus *Acanthastrea*). *Journal of Natural History*, 22(1), 263–279. <https://doi.org/10.1080/00222938800770201>
- Shokri, M. R., & Kabiri, K. (2025a). Coral Reefs of Iran. In *Coral Reefs of Iran* (pp. 19–49). Springer Nature Switzerland. https://doi.org/10.1007/978-3-032-00598-4_2
- Shokri, M. R., & Kabiri, K. (2025b). Scleractinian Corals of Iran. In M. R. Shokri & K. Kabiri (Eds.), *Coral Reefs of Iran: Biodiversity and Distribution in Extreme Environments* (pp. 51–183). Springer Nature Switzerland. https://doi.org/10.1007/978-3-032-00598-4_3
- Skirving, W. J., Heron, S. F., Marsh, B. L., Liu, G., De La Cour, J. L., Geiger, E. F., & Eakin, C. M. (2019). The relentless march of mass coral bleaching: A global perspective of changing heat stress. *Coral Reefs*, 38(4), 547–557. <https://doi.org/10.1007/s00338-019-01799-4>
- Smith, E. G., Hazzouri, K. M., Choi, J. Y., Delaney, P., Al-Kharafi, M., Howells, E. J., Aranda, M., & Burt, J. A. (2022). Signatures of selection underpinning rapid coral adaptation to the world's warmest reefs. *Sci Adv*, 8(2), eabl7287. <https://doi.org/10.1126/sciadv.abl7287>
- Spalding, M. D., Fox, H. E., Halpern, B. S., McManus, M. A., Molnar, J., Allen, G. R., Davidson, N., Jorge, Z. A., Lombana, A. L., Lourie, S. A., Martin, K. D., McManus, E., Molnar, J., Recchia, C. A., & Robertson, J. (2007). Marine ecoregions of the world: A bioregionalization of coastal and shelf areas. *BioScience*, 57(7), 573–583. <https://doi.org/10.1641/B570707>
- Sully, S., Burkepile, D. E., Donovan, M. K., Hodgson, G., & Van Woesik, R. (2019). A global analysis of coral bleaching over the past two decades. *Nature Communications*, 10(1), 1264. <https://doi.org/10.1038/s41467-019-09238-2>
- Tagomori, I. S., Diuana, F. A., Baptista, L. B., Bertram, C., Dafnomilis, I., Drouet, L., Fosse, F., Fragkiadakis, D., Fricko, O., Hooijschuur, E., Iyer, G., Kikstra, J. S., Krey, V., Luderer, G., Ou, Y., Reis, L. A., Richters, O., Rochedo, P. R. R., Vrontisi, Z., ... Van Vuuren, D. (2026). Promising climate progress from net-zero ambitions to the Paris Agreement goal. *Nature Climate Change*, 16(5), 550–557. <https://doi.org/10.1038/s41558-026-02615-y>
- Torquato, F., Bouwmeester, J., Range, P., Marshall, A., Priest, M. A., Burt, J. A., Møller, P. R., & Ben-Hamadou, R. (2022). Population genetic structure of a major reef-building coral species *Acropora downingi* in northeastern Arabian Peninsula. *Coral Reefs*, 41(3), 743–752. <https://doi.org/10.1007/s00338-021-02158-y>

- Torquato, F., & Møller, P. R. (2020). Physical-biological interactions underlying the phylogeographic patterns of coral-dependent fishes around the Arabian Peninsula. *Ecology*. <https://doi.org/10.1101/2020.01.27.921411>
- Van Hooideonk, R., Maynard, J., Tamelander, J., Gove, J., Ahmadi, G., Raymundo, L., Williams, G., Heron, S. F., & Planes, S. (2016). Local-scale projections of coral reef futures and implications of the Paris Agreement. *Scientific Reports*, 6(1), 39666. <https://doi.org/10.1038/srep39666>
- Van Woesik, R., & Kratochwill, C. (2022). A global coral-bleaching database, 1980–2020. *Scientific Data*, 9(1), 20. <https://doi.org/10.1038/s41597-022-01121-y>
- Veron, J. E. N., Devantier, L. M., Turak, E., Green, A. L., Kininmonth, S., Stafford-Smith, M., & Peterson, N. (2009). Delineating the Coral Triangle. *Galaxea, Journal of Coral Reef Studies*, 11(2), 91–100. <https://doi.org/10.3755/galaxea.11.91>
- Wabnitz, C. C. C., Lam, V. W. Y., Reygondeau, G., Teh, L. C. L., Al-Abdulrazzak, D., Khalfallah, M., Pauly, D., Palomares, M. L. D., Zeller, D., & Cheung, W. W. L. (2018). Climate change impacts on marine biodiversity, fisheries and society in the Arabian Gulf. *PLOS ONE*, 13(5), e0194537. <https://doi.org/10.1371/journal.pone.0194537>
- Wiggert, J. D., Hood, R. R., Banse, K., & Kindle, J. C. (2005). Monsoon-driven biogeochemical processes in the Arabian Sea. *Progress in Oceanography*, 65(2–4), 176–213. <https://doi.org/10.1016/j.pocean.2005.03.008>
- Williams, G. J., & Graham, N. A. J. (2019). Rethinking coral reef functional futures. *Functional Ecology*, 33(6), 942–947. <https://doi.org/10.1111/1365-2435.13374>
- Williams, G. J., Graham, N. A. J., Jouffray, J., Norström, A. V., Nyström, M., Gove, J. M., Heenan, A., & Wedding, L. M. (2019). Coral reef ecology in the Anthropocene. *Functional Ecology*, 33(6), 1014–1022. <https://doi.org/10.1111/1365-2435.13290>
- Zeng, K., He, S., & Zhan, P. (2025). Inevitable global coral reef decline under climate change-induced thermal stresses. *Communications Earth & Environment*, 6(1), 827. <https://doi.org/10.1038/s43247-025-02790-4>

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8. Peer review

This report was reviewed by the IUCN Red List of Ecosystems global team and by members of other regional coral reef assessment teams under the Global Red List of Coral Reef Ecosystems initiative.

9. Disclaimer

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10. Contributors

In the modified version of the CRediT (<https://credit.niso.org/>) table below, all contributors are listed with their specific contribution(s) to the RLE assessment and publication.

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11. Annex

11.1. Boundary definitions

The ROPME Sea Area covers a strong environmental gradient, extending from the shallow and semi-enclosed Arabian (Persian) Gulf, through the Strait of Hormuz and Gulf of Oman, to the seasonally upwelling-influenced Arabian Sea (Claereboudt, 2019; Sheppard et al., 2010). Coral communities vary markedly across this gradient in species composition, diversity and community structure in response to differences in temperature and salinity regimes, circulation, bathymetry, turbidity, sedimentation and seasonal upwelling (Claereboudt, 2019; Rezai et al., 2004; Riegl & Purkis, 2012).

The six coral reef ecoregions used as assessment units were based on the Marine Ecoregions of the World (MEOW) framework (Spalding et al., 2007), with boundaries refined using published regional biogeographic studies and expert review to better represent ecological variation across the ROPME Sea Area (Claereboudt, 2019; Rezai et al., 2004; Riegl & Purkis, 2012; Sheppard et al., 2010). The names of the original MEOW ecoregions were retained throughout the assessment for consistency, with additional geographic descriptors added where they were subdivided into smaller assessment units. The original MEOW Arabian (Persian) Gulf ecoregion was subdivided into three assessment units, the Inner, Northeast and Southeast Gulf. The Northeastern Gulf captures the transition between the Arabian (Persian) Gulf and the Gulf of Oman, where conditions are influenced by water exchange through the Strait of Hormuz. The Inner Gulf represents reefs influenced by the distinct conditions of the inner basin, while the Southeast Gulf encompasses the shallow southern basin, characterized by strong seasonal temperature variability and high salinity. The Western Arabian Sea was similarly divided into North and South assessment units to reflect the strong ecological and oceanographic contrasts associated with the seasonal Indian Ocean monsoon. The principal boundary modifications and their rationale are summarized in Table A1.

Table A1. Units of assessment used in the **ROPME Sea Area** coral reef Red List of Ecosystems assessment, including the countries containing mapped reef habitat, estimated coral reef area, boundary definition and ecological justification.

Ecoregion	Country	Coral Reef Area (km ²)	Boundary Description	Justification
Western Arabian Sea – South	Oman	5.61	Southern subdivision of the MEOW Western Arabian Sea ecoregion, extending along the Dhofar coast. The northern boundary follows the transition from strong to weaker monsoon-driven upwelling; the offshore boundary follows the RSA limit.	Strong monsoon upwelling and heavy wave exposure support predominantly marginal coral communities, seasonal coral-macroalgal assemblages and geographically restricted fishes.
Western Arabian Sea – North	Oman	3.65	Northern subdivision of the MEOW Western Arabian Sea ecoregion, extending from the southern upwelling-dominated unit to Ras Al Hadd and the transition into the Gulf of Oman.	Weaker, more seasonal upwelling supports higher coral richness, localised <i>Montipora foliosa</i> frameworks and seasonal <i>Sargassum</i> and <i>Padina</i> beds.
Gulf of Oman	Iran, Oman, United	28.86	Broadly follows the MEOW	Oceanic salinity, regional

Ecoregion	Country	Coral Reef Area (km ²)	Boundary Description	Justification
	Arab Emirates		Gulf of Oman ecoregion from Ras Al Hadd to the Strait of Hormuz. The northern boundary was refined to distinguish the transitional conditions of the Strait and Arabian (Persian) Gulf	water exchange and localised upwelling support diverse framework-building and marginal reefs, with coral assemblages that are generally more diverse and structurally complex than those of the Arabian (Persian) Gulf.
Arabian (Persian) Gulf – Northeast	Iran, Oman	59.34	Northeastern subdivision of the original MEOW Arabian (Persian) Gulf ecoregion, extending along the Iranian coast into the Strait of Hormuz and Musandam. Its internal boundary follows regional transitions in circulation, bathymetry and coral communities.	Exchange with the Gulf of Oman produces a transitional environment between oceanic and Arabian (Persian) Gulf conditions. Reefs grade from structurally complex communities near the Strait to more stress-tolerant Gulf assemblages and retain higher coral diversity than the southern Gulf
Arabian (Persian) Gulf – Inner	Iran, Iraq, Kuwait, Saudi Arabia	44.97	Inner subdivision of the original MEOW Arabian (Persian) Gulf ecoregion, encompassing the restricted northern basin influenced by the Shatt al-Arab and limited circulation. It's boundary follows the transition to the Southeast and Northeast Gulf units.	Restricted circulation and Shatt al-Arab influence create strong gradients in salinity, temperature, turbidity and sedimentation. The unit includes offshore framework-building reefs and extensive marginal coastal systems adapted to highly variable environmental conditions.
Arabian (Persian) Gulf – Southeast	Bahrain, Saudi Arabia, Qatar, United Arab Emirates	489.75	Southern subdivision of the original MEOW Arabian (Persian) Gulf ecoregion, encompassing the shallow southern Gulf. Its northern boundaries follow transitions in bathymetry, circulation and environmental conditions towards the Inner and Northeast Gulf units.	Shallow, hypersaline waters experience extreme summer temperatures, high evaporation and recurrent Shamal winds. Reefs are predominantly marginal, with localised offshore frameworks, stress-tolerant massive corals and remnant <i>Acropora</i> communities.

11.2. Methods description

Data

A spatial representation of current coral reef extent across the RSA was compiled from multiple geospatial and observational sources. These included the UNEP-WCMC Global Distribution of Coral Reefs dataset; reef survey and monitoring coordinates provided by regional collaborators; habitat maps and reef layers supplied by researchers from the UAE, Iran and Oman; and historical peer-reviewed reef records compiled by the core team. Historical and published records from before 1995 were reviewed to identify reef locations that were absent or poorly represented in existing spatial datasets. These locations were retained in the current reef-extent layer only where reef persistence was corroborated by current monitoring sites, contemporary habitat maps, expert-contributed spatial layers or direct confirmation from regional experts. The outer boundary of the RSA was based on the five official coordinates listed in the 1978 Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment. These coordinates informed the boundary across the Gulf of Oman and the northern and southern Western Arabian

Sea. The conversion of these coordinates into the polygon used in the assessment included a manual spatial-processing step. The six ecoregion boundaries were intersected with the coastline and processed in UTM Zone 39N before outputs were returned to WGS 84. Bathymetric information from GEBCO was used as a general guide when refining the ecoregion boundaries. Boundaries followed marked changes in the bathymetric gradient rather than a fixed depth contour.

Reef surveyors and regional experts reviewed an initial version of the compiled reef extent map during the regional RLE workshop at NYU Abu Dhabi. Participants proposed additions, removal and adjustment based on field experience and current knowledge of reef occurrence. Further revisions were discussed during subsequent virtual meetings and implemented iteratively in QGIS and R. The agreed rules for refining the reef layer were: 1) UNEP-WCMC polygons were replaced or removed where higher-resolution habitat information was available or where location-specific coastal buffers were required; 2) a 300 m buffer was applied to offshore and nearshore monitoring sites, except in Musandam, where a 200 m coastal buffer was used to account for fjord topography; 3) the Iranian habitat layer was buffered by 10 m radius to reduce granularity and, lastly, 4) polygon or points were removed where expert review indicated that reefs were no longer present or where mapped features overlapped land, harbors, ports or other coastal infrastructure.

The revised source layers were transformed to UTM Zone 39N, validated geometrically, combined, intersected with the six ecoregions and dissolved by ecoregion. Final spatial outputs were stored in WGS 84 and reef area was calculated for each ecoregion in UTM Zone 39N. A full description of the spatial methodology along with access to the spatial map can be found in a forthcoming data paper (Al-Gergawi et al., 2026).

The biological dataset used in the assessment comprised benthic survey data collected across the region from 1987 to 2025. Observations included estimates of hard coral and other benthic cover, with taxonomic resolution ranging from broad benthic categories to species-level identifications, depending on the original survey. The database integrated data collected using line-intercept transects, point-intercept transects, video-based point-intercept transects and photoquadrats. Survey data were harmonized into a common structure while retaining information on the original monitoring method, sampling unit, location, survey date and data source. Survey locations were assigned to one of the six assessment ecoregions based on their geographic coordinates.

The database brought together data from 18 providers, including national monitoring programs, individual research projects and published studies. Site names and geographic coordinates were reviewed across datasets to identify repeated observations from the same monitoring sites through time and to resolve inconsistencies in site identity. Confirmed corrections to site names, coordinates, and country assignments were applied through a documented manual curation process while retaining the provenance of individual records. Harmonized monitoring-site identifiers were then used to link observations considered to represent the same reef site across datasets and survey years. The resulting consolidated regional dataset of reef benthic communities is described in a forthcoming data paper (Bento et al., 2026), which provides a detailed account of the data sources, survey methods, harmonization procedures, quality-control workflow and technical validation. Additional historical benthic information was compiled from

published articles, technical reports and books. These sources complemented the quantitative regional monitoring database by extending the temporal and geographical evidence available for the assessment. They were used to estimate and validate historical baseline conditions for the benthic indicators assessed under Criterion D. A list of these historical sources is provided in Supplementary Table S1.

Reef typology

To determine which coral reef types to include in this assessment, we used the IUCN Global Ecosystem Typology (GET) to ensure a consistent and globally aligned definition of coral reef ecosystems.

Within the GET, true photic coral reefs are classified under the ecosystem functional group 'M1.3 Photic Coral Reefs'. These ecosystems are characterised by active carbonate accretion and the development of a biogenic reef framework built primarily by Scleractinia over millennial timescales, i.e. net biogenic accretion. However, coral communities also occur in marginal environments where environmental conditions or substrate constrain carbonate accretion and limit the development of reef structures. These systems were defined as 'marginal' coral reefs in this assessment.

To ensure the assessment captures the full diversity of coral reef ecosystems globally, an inclusive and standardised approach was adopted. Within the ROPME Sea Area, both true (Type A) and marginal (Type B) reefs were included, recognising that marginal reefs constitute a large proportion of the region's coral habitats. Throughout much of the RSA, particularly in the environmentally extreme Arabian (Persian) Gulf and the monsoon-influenced Arabian Sea, coral communities commonly occur as low-relief "coral carpet" systems where environmental conditions limit substantial carbonate framework development. In contrast, well-developed true reef frameworks are largely restricted to specific locations, including offshore islands in Kuwait and Saudi Arabia, parts of the Gulf of Oman, the Musandam Peninsula, and isolated localities such as the Bar Al Hikman Peninsula in Oman (Claereboudt & Bruss 2025; Sheppard & Salm 1988). Mesophotic coral reefs and rocky reefs (Type C), which are classified under their own ecosystem functional groups in the GET (e.g. M1.6 Subtidal rocky reefs), were excluded from the assessment. Care was taken not to exclude degraded coral reefs that may superficially resemble rocky or other reef systems, as these represent important expressions of coral reef degradation and are central to assessing collapse risk. Reef occurrence and typology were determined using regional expert knowledge, field observations, available coral reef spatial datasets, monitoring records and published literature.

Criterion A: Reduction in geographic distribution

Criterion A assesses the reduction in the extent of an ecosystem over time, typically over a 50-year period. We focused on assessing subcriterion A1, which measures the percentage of coral reef area lost across each ecoregion over the past 50 years (1975–2025). Subcriteria A2a, A2b or A3, requiring assessment into the future, were not evaluated. For coral reefs, historical mapped reef area data spanning five decades are rarely available. In addition, coral reefs can undergo functional decline, without any visible change in the structural extent mapped by satellites. Consequently, direct estimation of mapped reef-area reduction was not possible. Following Obura

et al. (2021), we used the most recent estimate of hard coral cover from monitoring sites surveyed between 2020 – 2025 as a proxy for declines in reef area.

Hard coral cover was summed across taxonomic records within each sampling unit and then averaged across sampling units within each survey event. Where multiple survey events occurred at the same monitoring site within a year, survey-event means were averaged to produce annual site-level estimates. Monitoring sites were included when their most recent survey was conducted between 2020 and 2025, and hard coral cover from the most recent surveyed year was used to represent current conditions.

Each reef site was classified as functioning or collapsed using a hard-coral-cover threshold of 5%. This represents a conservative threshold relative to the approximate 10% coral-cover threshold below which coral abundance may be insufficient to maintain positive carbonate accretion (Perry et al., 2013). Sensitivity analyses were conducted using thresholds (1–10%) to evaluate how results change across plausible collapse thresholds. Within each ecoregion, the proportion of collapsed sites was calculated by giving every monitoring site equal weight. All sites included in the analyses were assumed to have represented functioning coral reef ecosystems at the beginning of the assessment period (1975). In addition, to account for reefs no longer represented by current monitoring, 26 additional sites known to have collapsed or been permanently lost due to anthropogenic or environmental pressures, such as land reclamation, dredging, coastal development, sedimentation, and severe bleaching, were compiled through expert assessment. These sites were assigned to ecoregions using their geographic coordinates and included as collapsed sites in the analysis.

Current (and additional degraded) monitoring sites were mapped against the spatial extent of coral reefs to determine the coverage and representativeness of existing monitoring efforts. Monitoring coverage was reviewed in relation to the reef Extent of Occurrence (EOO; see subcriterion B1) and the distribution of reef-occupied 10*10 km grid cells used to calculate Area of Occupancy (AOO; subcriterion B2). Expert judgment was used to evaluate whether the available monitoring data were sufficient to represent ecosystem-level change within each ecoregion. As a general guideline, ecoregions represented by fewer than three monitoring sites were considered insufficiently sampled and were classified as Data Deficient (DD), unless additional evidence indicated that the available sites were representative of the ecoregion.

Where data were adequate, risk categories were assigned according to the Red List of Ecosystems thresholds for subcriterion A1, corresponding to declines of $\geq 80\%$ (Critically Endangered), $\geq 50\%$ to $< 80\%$ (Endangered), $\geq 30\%$ to $< 50\%$ (Vulnerable), $\geq 27\%$ to $< 30\%$ (Near Threatened), and $< 27\%$ (Least Concern) (see Table A2).

Table A2. IUCN RLE thresholds for assigning threatened categories under Criterion A, based on the proportional decline in ecosystem distribution over the time frame specified for each subcriterion. CR = Critically Endangered; EN = Endangered; VU = Vulnerable.

Subcriterion	Time frame	CR	EN	VU
A1	Past (over the past 50 years)	≥ 80%	≥ 50%	≥ 30%
A2a	Future (over the next 50 years)	≥ 80%	≥ 50%	≥ 30%
A2b	Any 50-year period (including past, present and future)	≥ 80%	≥ 50%	≥ 30%
A3	Historical (since approximately 1750)	≥ 90%	≥ 70%	≥ 50%

Criterion B: Restricted Geographic Distribution

Criterion B assesses ecosystems whose **geographic distribution is so limited** that they are at **risk of collapse** due to the chance occurrence of **one or a few threatening events**, such as a cyclone, bleaching event, or disease outbreak (Keith et al., 2024).

To assess Criterion B, the RLE uses **two standardised spatial metrics**:

- (i) **Subcriterion B1: Extent of Occurrence (EOO)** – the area within the outer boundary of the ecosystem’s known distribution;
- (ii) **Subcriterion B2: Area of Occupancy (AOO)** – the area occupied by the ecosystem, measured using 10 by 10 km grid cells.

Selection and validation of coral reef extent layer:

The analysis requires a spatial layer representing the current distribution of coral reefs. The layer was developed by integrating the **Millennium Coral Reef Mapping Project** layer curated by the **UNEP World Conservation Monitoring Centre (UNEP-WCMC)**, with reef and habitat maps contributed by regional collaborators, reef survey coordinates, historical reef records supported by contemporary evidence, and regional expert knowledge. The compiled reef extent layer was reviewed by regional experts, who identified areas where reef extent appeared to be over- or under-represented and incorporated localised corrections into the selected layer. Once the validated coral reef extent layer was projected using the **WGS 84 / UTM zone 39N (EPSG:32639)** coordinate reference system, the *makeEOO* function in the *redlistr* package in R (version 2.0.0) was used to generate the minimum convex polygon representing the EOO of each ecoregion. The *getAreaEOO* function was then used to calculate the EOO area in km². For subcriterion B2, the *getAOO* function was used to overlay a 10 x 10 km grid over the reef extent layer and the number of grid cells containing coral reefs was counted to estimate the AOO. All grid cells whose cumulative area of the reef ecosystem was <1% were excluded from the AOO count.

To determine the risk category under Criterion B, EOO and AOO values were compared against the thresholds defined in the Red List of Ecosystems (RLE) guidelines (Table A3). Ecoregions with EOO or AOO values within 10% of the VU thresholds were classified as Near Threatened (NT).

Finally, to formally assign the risk status under subcriterion B1 or B2 for each ecoregion, experts were required to justify observed or inferred declines in reefs, or the presence of current threats, such as ocean warming, pollution, coastal development, or overfishing, that present an ongoing risk to coral reefs.

Table A3. IUCN RLE thresholds for assigning threatened categories under Criterion B, based on Extent of Occurrence (B1), Area of Occupancy (B2) and the number of threat-defined locations (B1 and B3). CR = Critically Endangered; EN = Endangered; VU = Vulnerable; EOO = Extent of Occurrence; AOO = Area of Occupancy.

[illegible]

Criterion C

Criterion C evaluates the degradation of abiotic conditions that support an ecosystem's functioning and persistence. The goal is to evaluate whether abiotic conditions have changed to such an extent that they pose a significant risk to the ecosystem's ability to sustain its characteristic biota and ecological processes. Such changes may arise from alterations in disturbance regimes, including events such as floods, fires or storms.

Ocean warming and marine heatwave events have emerged as one of the largest issues affecting coral reefs around the world, often inducing widespread and severe coral bleaching and mortality. Accordingly, the analysis for this criterion was designed to capture broad-scale changes in the abiotic environment associated with the increasing frequency of extreme marine heatwave events (Emslie et al., 2024; Heron, et al., 2016; Hughes et al., 2018), and determine how present and future environmental conditions threaten the survival and persistence of coral reef ecosystems.

Indicator selection

Recurrent heatwaves reduce the environmental suitability for reef-building corals through several pathways. A shift in disturbance regime increases the risk of large-scale coral mortality and affects the establishment and persistence of species (Elma et al., 2023; Mudge & Bruno, 2023). These changes can be associated with substantial declines in coral abundance, reduced structural complexity, and lower carbonate accretion rates (Williams et al., 2019; Williams & Graham, 2019). Additionally, recurrent bleaching episodes weaken coral communities, reduce reproductive output, and increase susceptibility to other stressors such as disease (Briggs et al., 2024; Byrne et al., 2025; Croquer & Weil, 2009; Levitan et al., 2014). As these events become more frequent, intervals between disturbances are shortened, preventing meaningful coral recovery and increasing the likelihood of progressive ecosystem degradation and eventual collapse (Emslie et al., 2024; Hughes et al., 2018). To assess the likelihood of recurrent heat waves driving ecosystem collapse at regional scales, we assessed two plausible and distinct pathways, each requiring a different analytical approach.

The first is a **chronic (press) pathway**, driven by the cumulative effects of recurrent bleaching events that weaken coral communities, reduce growth and reproductive output, and increase susceptibility to secondary stressors such as disease. As bleaching events become more frequent, recovery intervals shorten, preventing meaningful recovery between disturbances and leading to progressive ecosystem degradation over time. The second is an **acute (pulse) pathway**, characterised by rapid decline following a small number of extreme heat stress events occurring over a short period. These events can cause widespread mortality across coral taxa, including stress-tolerant species, leading to near-complete coral loss and triggering collapse.

We assessed the relative change in disturbance conditions over:

- the past 50 years (1975–2025) as part of subcriterion C1, and
- 50 years into the future (2026–2075) for subcriterion C2

For the **chronic pathway**, the indicator is the expected number of severe bleaching events over a 30-year period, expressed as an average return interval (years between events).

For the **pulse pathway**, the indicator is the maximum number of severe mortality events within any 5-year moving window.

Using DHW as a proxy for bleaching events

For both pathways, Degree Heating Weeks (DHW), a measure of the accumulation of heat stress over a rolling 12-week window, was used to approximate the occurrence of severe bleaching and mortality events (Liu et al., 2012).

Although data on historical bleaching observations exist (Donner et al., 2017; Eakin et al., 2026; van Woesik & Kratochwill, 2022), they are not spatially or temporally extensive. DHW data are globally available since 1985, including for future climate projections (Mellin et al., 2024; Skirving et al., 2019), and are underpinned by a well-documented, long-term relationship with coral bleaching across many regions globally (Heron, Johnston, et al., 2016; Liu et al., 2005; Sully et al., 2019). Values of **DHW ≥ 4** are associated with bleaching onset, while values of **DHW ≥ 8** or more are historically linked to widespread coral mortality (Kayanne, 2017; Liu et al., 2005; Skirving et al., 2019). In addition, DHW has been widely used in recent studies assessing bleaching risk under climate change (Beyer et al., 2018; Bozec et al., 2025; Mellin et al., 2024; Obura et al., 2021), and is supported by established thresholds linking DHW levels to bleaching severity developed by the NOAA Coral Reef Watch (https://coralreefwatch.noaa.gov/product/5km/index_5km_baa-max-7d.php). While DHW may not be the most precise predictor of bleaching severity at fine spatial or temporal scales, it provides a robust, scalable, and comparable indicator of bleaching risk suitable

for capturing broad trends in disturbance regimes over time, and supports a standardised approach across ecoregions.

Data

Subcriterion **C1** was assessed using satellite-measured DHW from NOAA Coral Reef Watch at a spatial resolution of 5 km (Liu et al., 2012). The standard RLE assessment timeframe is 50 years; however, satellite measurements of DHW began 40 years ago in 1985. For the period 1975–1984, thermal conditions were assumed to be broadly comparable to those observed during the earliest decade of the satellite record (1985–1995). This assumption is supported by the fact that the first global mass bleaching event occurred later, in 1997–1998 (Hoegh-Guldberg, 1999), and that global ocean heat content has been consistently above average since the mid-1990s, with ocean warming accelerating further since the late 90s and early 2000s (Cheng et al., 2017, 2023; Heron, Maynard, et al., 2016; Merchant et al., 2025). The 1985–1995 period is therefore the closest available proxy for late-1970s thermal stress regimes. DHW values were spatially attributed to each reef pixel using a 50 km buffer, retaining only data from pixels within this distance of mapped reef extent, and assigning values through an interpolation process.

Subcriterion **C2** used modelled climate projections of daily Degree Heating Weeks from Mellin et al. (2024) for 1985–2100, available for three climate pathways: **SSP2-4.5**, **SSP3-7.0**, and **SSP5-8.5**. The dataset did not include projections corresponding to the Paris Agreement pathway (SSP1-1.9; approximately 1.5–2°C warming by 2100), which is considered increasingly unrealistic given current global emissions trajectories (Tagomori et al., 2026). All three scenarios with data were assessed to explicitly demonstrate how the degree of climate mitigation affects risk outcomes for coral reefs. The highest emissions scenario (SSP5-8.5) represents an extreme case that is considered increasingly unlikely to eventuate (Sarofim et al., 2024), therefore, **SSP2-4.5** and **SSP3-7.0** were treated as the primary scenarios.

For both C1 and C2, daily DHW data were converted to an annual maximum value for each reef pixel by first calculating the monthly maximum, and then extracting the highest value recorded from each local summer season. In regions where the summer season straddles two calendar years (e.g. the thermal peak occurs during November–March), the seasonal maximum was attributed to the year the stress began. This produced an annual time series of maximum DHW for each reef pixel spanning the historical and future assessment periods.

Thresholds

To convert the annual maximum DHW data into a record of disturbance events, ecoregion-specific DHW thresholds were applied to classify each year as an event (value of 1) or not (value of 0). The DHW thresholds used for this classification differed between the two pathways, reflecting their distinct ecological mechanisms.

For the **chronic pathway**, a severe bleaching event is defined as one in which widespread bleaching occurs across approximately more than 50% of coral colonies. These events cause substantial loss of thermally sensitive species but may not typically reach the intensity required to cause widespread mortality of stress-tolerant taxa. For the **pulse pathway**, a severe mortality event is defined as an extreme, high-intensity thermal stress event that causes widespread mortality (more than 50% of colonies) across all coral taxa, including stress-tolerant species. Applying the thresholds produced two binary event time series for each reef pixel which forms the basis of the chronic and pulse analyses.

DHW thresholds corresponding to severe bleaching events (chronic pathway) and severe mortality events (pulse pathway) for each ecoregion were informed by historical observations of coral reef responses to marine heatwaves, specifically the levels of thermal stress associated with

widespread bleaching and coral mortality. These thresholds were not treated as fixed, as the DHW level required to trigger a given bleaching response is expected to change over time. For example, in the 1980s and 90s, relatively lower DHW values may have resulted in severe bleaching and mortality (Hoegh-Guldberg 1999), whereas coral communities today (or in the future) may be altered or acclimated, potentially requiring higher DHW values to trigger comparable responses (Heron et al., 2016; Pratchett et al., 2013; Sully et al., 2019). For C2, thresholds were informed by bleaching responses to thermal stress levels observed during the most recent years of the satellite record (2015–2025) and were retained or adjusted upward into the future to account for anticipated species filtering, and potential thermal adaptation or acclimation. Thresholds were defined at the ecoregional level where locally relevant evidence supported this. To account for uncertainty in the exact level of heat stress that causes bleaching/mortality, two plausible DHW threshold values were applied for each pathway.

Ecoregion-specific thresholds were determined by comparing documented bleaching and mortality events with annual maximum DHW values from observed records. The primary threshold was the value considered most likely to represent the onset of widespread severe bleaching or mortality, while an alternative value was included where there was uncertainty. Thresholds were allowed to vary over time to account for changes in thermal exposure and possible changes in coral resilience. Where direct evidence was limited, values were informed by the DHW records, evidence from neighbouring ecoregions and expert judgement. For future projections, recent thresholds were either retained or increased to account for possible species filtering, adaptation or acclimation. The thresholds used for each ecoregion and period are presented in Table A4.

Calculation of decline and risk

Current values

To apply Criterion C, the RLE assesses the level of risk based on the **severity of decline** and the **proportion of the ecosystem affected**. Analyses were conducted independently for each pathway (chronic and pulse). The relative severity of decline for both subcriteria C1 and C2 was calculated for each reef pixel using the formula:

$$\text{Relative severity of decline (\%)} = (\text{current conditions} - \text{initial conditions}) / (\text{collapse threshold} - \text{initial conditions}) \times 100$$

The **chronic pathway** is assessed in terms of the average return interval of severe bleaching events over a 30-year period (DeCarlo & Whitaker, 2025; Hughes et al., 2018). Return interval is an ecologically meaningful indicator because recovery from disturbance is a slow process, typically requiring 10–15 years for fast-growing species and considerably longer for the full complement of coral life histories and morphologies (Gilmour et al., 2013; Robinson et al., 2019). As bleaching events become more prevalent and frequent, the combined effect of repeated mortality and shortened intervals between disturbances limiting recovery, drives cumulative coral loss and increases the likelihood of ecosystem-level collapse (Eakin et al., 2026, p. 201; Hughes et al., 2018; Pratchett et al., 2021).

Return intervals were estimated by fitting a binomial (logistic) regression model to the binary bleaching event time series for each reef pixel, where the probability of a severe bleaching event in any given year is modelled as a function of time (DeCarlo & Whitaker, 2025). This probabilistic approach provides a continuous, smoothed estimate of annual event probability. This reduces sensitivity to interannual variability and characterises the underlying trajectory of disturbance regimes, making it well suited to assessing chronic, long-term stress. The modelled annual

probabilities were summed across all possible 30-year windows within the assessment periods of C1 (1985/6–2025) and C2 (2026–2075) to determine the expected number of severe bleaching events, which was then converted to an average return interval by dividing 30 years by the expected number of events. The current condition value was based on the shortest return interval (highest disturbance) over all 30-year periods. For C1, the model was fitted using observed DHW data (1985–2025), and for C2, the models were fitted using projected DHW data (1985–2100).

For the **pulse pathway**, current conditions were assessed using a 5-year moving window, applied across the full assessment periods of C1 and C2 for each reef pixel. The number of severe mortality events within each window was counted, with the maximum count across any 5-year period, representing the highest observed or projected clustering of extreme events, used as the current condition value. This event-based approach preserves temporal variability and is specifically designed to capture the clustering of extreme events that characterises the acute collapse pathway.

Initial values

To calculate relative severity of decline, initial values reflecting the baseline disturbance regime of each assessment period (C1 and C2) must be established.

For the **chronic pathway**, under C1, historical baseline conditions (circa the 1970s) are characterised by bleaching events occurring at most once every 10–15 years, equivalent to approximately 2–3 events per 30-year period. This reflects a natural disturbance regime in which sufficient time elapsed between events for meaningful coral recovery (Baker et al., 2008; Gilmour et al., 2013; Graham et al., 2011; Hughes et al., 2018; Robinson et al., 2019). For C2, the initial value is calculated from projected DHW data over the 30-year period immediately preceding 2026 (1996–2025), using the same probabilistic framework applied to the rest of the C2 analysis.

For the **pulse pathway**, under C1, the initial value is the maximum number of severe mortality events within any 5-year window at the start of the satellite time series (1985/86–1990/91). For C2, the initial value is the maximum number of severe mortality events within any 5-year window during the decade immediately preceding 2026 (2016–2025).

Collapse thresholds

To complete the calculation of relative severity of decline, it is necessary to define a collapse threshold, when the frequency of damaging heat waves creates a high likelihood of collapse. For coral reefs, collapse is defined by the near or complete loss of hard corals, corresponding to a **hard coral cover of 5% or less**. The same collapse thresholds are applied to both C1 and C2 because conceptually similar environmental conditions should lead to similar ecological outcomes regardless of when they occur. Severe bleaching events were identified using ecoregion-specific DHW thresholds, which account for regional differences in coral responses to thermal stress and, where appropriate, changes in responses over time (Table A4).

For the **chronic pathway**, the collapse threshold is defined as severe bleaching events occurring, on average, every 3 years over a 30-year period (approximately 10 events per 30-year window) (DeCarlo & Whitaker, 2025). At this frequency, recovery intervals are considered insufficient to permit meaningful coral recovery between disturbances, and the cumulative, iterative mortality caused by several events drives progressive and significant ecosystem degradation (Emslie et al., 2024; Hughes et al., 2018). As a sensitivity test, a threshold of one event every 5 years (~6 events per 30-year window) was also assessed as even these narrow recovery windows do not allow for full recovery, and will lead to substantial decline after multiple decades (Hughes et al., 2018). Annual severe bleaching is commonly cited as a threshold when predicting future reef outlooks

(De Clippele et al., 2023; van Hooideonk et al., 2016; Zeng et al., 2025), however it is considered overly conservative as collapse will likely occur before we reach conditions conducive to yearly bleaching (Bland et al., 2017; Obura et al., 2021).

For the **pulse pathway**, the primary collapse threshold is defined as three severe mortality events occurring within any 5-year window. A sensitivity threshold of two events within five years was also assessed. This formulation was adopted in response to evidence that the collapse threshold used by Obura et al. (2021) for the Western Indian Ocean, and Bland et al. 2017 for the Meso-American Reef of two severe bleaching events per decade (equivalent to approximately one event every 5 years), may be insufficient to drive collapse under current conditions. Several reefs, including the Great Barrier Reef and Little Cayman, have experienced two or more severe bleaching events within a decade between 2015/16 and 2025 without clear evidence of ecosystem collapse (Emslie et al., 2024; Henley et al., 2024; Pratchett et al., 2021). This suggests that reefs may be more resilient to moderate clustering of events than previously assumed, and that a higher frequency is required to reliably indicate conditions conducive to collapse. The primary pulse collapse threshold was therefore set as three severe mortality events within any five-year window, while two events within five years were evaluated as a sensitivity threshold.

Table A4. Ecoregional DHW thresholds representing thermal stress levels resulting in widespread bleaching for the chronic pathway. Thresholds can be time-varying to represent changing coral responses and increased warming.

Ecoregion	C1 – observed, past 50 years (1975–2025)		C2 – predicted, future 50 years (2026–2075)	
	Timeframe	Severe mortality (DHW range)	Timeframe	Severe mortality (DHW range)
Western Arabian Sea – South	1985-2009	2-3	2026 - 2075	3-5
	2010-2025	3-4		
Western Arabian Sea – North	1985-2002	2-3	2026 - 2075	4-6
	2003-2016	3-4		
	2017-2025	4-5		
Gulf of Oman	1985-2003	3-4	2026 - 2075	6-10
	2004-2020	6-8		
	2021-2025	6-10		
Arabian (Persian) Gulf – Northeast	1985-2018	3-4	2026 - 2075	3-5
	2019-2025	3-5		
Arabian (Persian) Gulf – Inner	1985-2009	6-8	2026 - 2075	8-12
	2010-2025	8-12		
Arabian (Persian) Gulf – Southeast	1985-2014	2-3	2026 - 2075	4-8
	2015-2025	4-6		

Risk status assignment

To assign the risk status under subcriteria C1 and C2 for each ecoregion, relative severity of decline was interpreted in conjunction with reef extent using the **severity–extent matrix** (Figure A1). The relative extent of decline for each ecoregion was approximated from the cumulative proportion of reef area experiencing different levels of decline ($\geq 20\%$, $\geq 30\%$, $\geq 50\%$, $\geq 70\%$, $\geq 80\%$, and 100%).

Where results differ between the chronic and pulse pathways, the more severe primary risk category was reported. Uncertainty across DHW thresholds, collapse thresholds, and initial values was incorporated by repeating the analysis across all plausible combinations of these parameters, producing a range of possible risk outcomes. The final reported risk status for each ecoregion for C1 was based on the primary thresholds, using the binomial approach for the chronic pathway and the event-based approach for the pulse pathway. For C2, the final status corresponded to the best-case scenario of an intermediate climate pathway (SSP2-4.5) with coral adaptation (higher future DHW thresholds). The final Criterion C status was determined by taking the highest threat category across subcriteria C1 and C2.

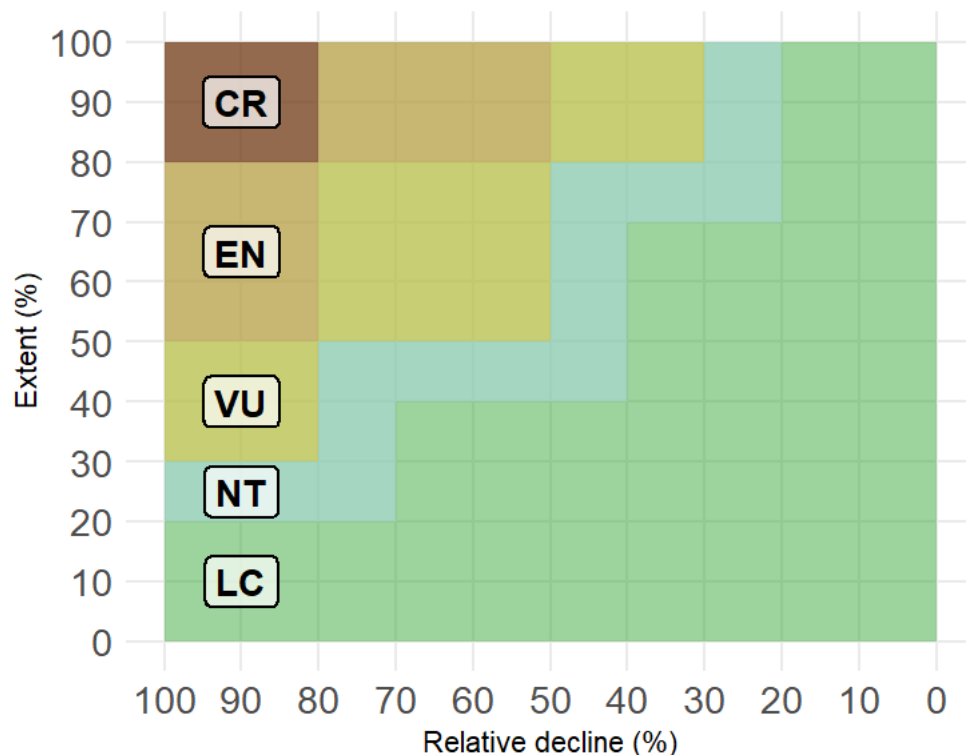


Figure A1. Severity-extent matrix used to assign risk categories under Criterion C and D. Risk categories are by combining the relative severity of decline with the proportion of the ecosystem affected. For Criterion C, extent represents the proportion of reef area affected; for Criterion D, it represents the proportion of monitoring sites exceeding the specified decline threshold. CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern.

Criterion D: Disruption of Biotic Processes and Interactions

Criterion D was evaluated to identify ecosystems experiencing severe disruption to biotic organisms, processes and interactions. This includes declines in characteristic species, shifts in community structure, and the loss of ecological functions necessary for maintaining ecosystem identity. The approach enables identification of the most degraded ecosystem components and how this degradation contributes to the overall risk of collapse. This assessment evaluated the degradation over the past 50 years (sub-criterion D1), estimating how close each ecosystem component was to collapse or severe functional disruption.

Indicator selection

In the ROPME Sea Area, three key biotic components were assessed using benthic cover data derived from standard underwater survey methods, including point-intercept transects, line-intercept transects, video-based point-intercept transects and photoquadrats. These components include:

- Hard corals, as the keystone ecosystem taxa responsible for forming the habitat structure and accretion processes;
- Branching corals, as structurally complex and disturbance-sensitive components of coral reef communities
- Macroalgae, as the principal competitive taxa to hard corals;

For each component, indicators were selected based on ecological relevance, data availability, spatial and temporal coverage, sensitivity to ecosystem condition, and the ability to define both a reference state and a collapse threshold.

Hard coral cover was selected as the indicator of coral abundance, as it has been consistently used as a key measure of reef health over several decades (Guest et al., 2018). Algae-to-coral cover ratio was used to represent benthic competition, rather than algae cover alone, as this directly captures the dynamic balance between coral and algal dominance (Obura et al., 2022). Algae included macroalgae and turf algae, together with records identified only as “Algae” where finer taxonomic resolution was unavailable. Crustose coralline algae were excluded because they contribute to reef accretion and do not represent competitive algal overgrowth. The ratio was calculated as the total algae cover divided by the sum of algae and hard coral cover.

The proportion of total hard coral cover composed of branching corals, i.e. branching coral ratio, was selected as an indicator of coral community degradation and reef structural complexity. Branching corals contribute disproportionately to three-dimensional reef habitat complexity and provide important habitat for reef-associated organisms (Kembrey et al., 2024; Oh et al., 2025). Within the RSA, this functional group is represented primarily by the genera *Acropora*, *Pocillopora* and *Stylophora* (Burt, 2024; Claereboudt, 2019; Hadj-Hammou et al., 2025). Branching-coral records were therefore restricted to hard corals identified as one of these three genera. Cover values were standardised as percentages and summed across the three genera within each sampling unit. The indicator quantifies changes in coral community composition rather than changes in absolute coral cover.

Fish-based indicators of herbivory and piscivory were considered but were not included in the regional Criterion D assessment because comparable historical and contemporary fish data were insufficient to characterise these ecological processes at the ecoregional scale.

Calculation of risk

Biotic degradation under Criterion D was assessed using the relative severity of decline. This metric compares the current state of each indicator to both a historical baseline (level approximately 50 years ago) and a hypothetical collapse threshold.

Current values

Current values for each indicator were calculated at the site level using monitoring data available from 2020–2025. A “site” refers to a defined monitoring location where transects, quadrats or other sampling units are available, and at which data are aggregated. For all benthic indicators, percentage cover was first summed across relevant taxonomic records within individual sampling units and then averaged across sampling units within each survey event. Where multiple survey events occurred at the same site within a year, survey-event means were averaged to obtain annual site-level cover estimates. Annual site-level hard coral cover was used directly as the hard coral indicator. Annual site-level algae and hard coral cover estimates were combined to calculate the algae-coral ratio for each site-year. Annual site-level branching coral cover was divided by annual hard coral cover to calculate the branching coral ratio for each site-year. Site-year records with missing or zero total hard coral cover were excluded, and ratios were checked to ensure that values fell between zero and one. Where multiple annual values were available for a monitoring site between 2020 and 2025, the most recent annual value was retained for each indicator. These site-level values were then used to calculate the ecoregional means presented in Table A5.

Table A5. Mean current value for each Criterion D indicator per ecoregion between 2020 and 2025 (n = number of current monitoring sites).

Ecoregion	Indicator	n	Mean	Std. dev	Min value	Max value
Western Arabian Sea – South	Hard coral cover	11	21.2	7.2	4.6	29.6
Western Arabian Sea – North	Hard coral cover	3	47.5	16.4	28.9	60.1
Gulf of Oman	Hard coral cover	29	34.0	18.2	4.1	70.5
Arabian (Persian) Gulf – Northeast	Hard coral cover	5	50.2	20.5	17.1	69.2
Arabian (Persian) Gulf – Inner	Hard coral cover	4	6.3	2.9	4.3	10.5
Arabian (Persian) Gulf – Southeast	Hard coral cover	30	8.0	5.6	0.3	20.1
Western Arabian Sea – South	Algae - coral ratio	-	-	-	-	-
Western Arabian Sea – North	Algae - coral ratio	-	-	-	-	-
Gulf of Oman	Algae - coral ratio	29	0.38	0.27	0.00	0.85
Arabian (Persian) Gulf – Northeast	Algae - coral ratio	5	0.20	0.19	0.00	0.50
Arabian (Persian) Gulf – Inner	Algae - coral ratio	4	0.08	0.04	0.05	0.13
Arabian (Persian)	Algae - coral	30	0.77	0.16	0.45	1.00

Ecoregion	Indicator	n	Mean	Std. dev	Min value	Max value
Gulf – Southeast	ratio					
Western Arabian Sea – South	Branching coral ratio	10	0.13	0.24	0	0.80
Western Arabian Sea – North	Branching coral ratio	-	-	-	-	-
Gulf of Oman	Branching coral ratio	29	0.17	0.24	0	0.95
Arabian (Persian) Gulf – Northeast	Branching coral ratio	5	0.21	0.22	0	0.52
Arabian (Persian) Gulf – Inner	Branching coral ratio	4	0.07	0.07	0	0.15
Arabian (Persian) Gulf – Southeast	Branching coral ratio	30	0.03	0.09	0	0.51

Initial values

A reference state representing conditions of each indicator approximately 50 years ago (circa 1975) was established to quantify long-term change. Monitoring data from this period were generally limited or unavailable across much of the ROPME Sea Area as consistent and standardised long-term reef monitoring was not established across the region until early 2000s, with several national programs beginning even later.

Baseline conditions were therefore reconstructed using a combination of empirical data, literature and expert knowledge. These estimates represent conditions across the whole ecosystem within each ecoregion and were derived as distributions (e.g., mean and standard deviation) rather than single values to account for natural variability and to incorporate uncertainty.

To determine the most suitable approach for deriving initial values, the first step was to consider the likely condition of reefs in each ecoregion in the mid-1970s for the selected indicators, specifically, whether reefs were in relatively improved, pristine or degraded conditions. Two approaches to estimate initial values were explored and compared:

Method 1 – Literature-derived benthic baselines

Regional experts assumed that reef conditions in the 1970s were generally better than the present normative state, and that the widespread thermal bleaching events that affected the ROPME Sea Area during the mid- and late 1990s represented a major turning point in regional reef conditions. In particular, the severe bleaching event of 1996, followed by the 1997/8 global bleaching event, marked the onset of a widespread degradation across many reefs (Burt et al., 2011; Burt & Bauman 2020; Riegl, 2002; Sheppard et al., 2010). Therefore the condition of reefs prior to 1996 was considered broadly representative of earlier (1970s) conditions, with only localised degradation in places.

A literature review was conducted to compile published benthic data from early reef surveys, in the 1980s and 1990s. Historical records collected up to and including 1995 and considered by the regional expert group to be representative of broader reef benthic conditions were selected. These site-level data were averaged to estimate ecoregional baseline mean values and variance for hard coral cover. Historical branching coral ratios were calculated from the relative abundance of

Acropora and *Pocillopora* within the hard coral community and similarly aggregated to estimate ecoregional baseline mean values and variance. *Stylophora* was included in the monitoring-based indicator but could not be incorporated into historical baseline estimates because comparable published data were unavailable.

Method 2 – Maximum value approach

An alternative approach used long-term monitoring datasets to estimate baseline conditions. Sites with extended time series (≥ 10 years between the first and most recent survey, with observations from at least two survey years) were assumed to have experienced relatively good conditions at some point during the monitoring period. These records can provide an estimate of the ‘best’ conditions possible across reefs in an ecoregion, therefore acting as a proxy for “healthy” conditions around 1975.

For each monitoring site, baseline values were selected separately for each indicator, using the survey year that best represented the reference condition. The selected site-level values were combined within each ecoregion to estimate the mean and standard deviation of the baseline distribution. Where historical-derived baselines were available (1960s-1990s), these were compared with the monitoring-derived estimates to assess the consistency of the two approaches.

For hard coral cover, the maximum annual value was selected for each long-term monitoring site. For the algae-coral ratio, the value from the year of maximum hard coral cover was selected. For the branching coral ratio, the value from the year of maximum branching coral ratio was selected.

Both baseline approaches were compared where sufficient data were available. The resulting estimates were reviewed by the regional expert group, considering the quality, comparability and representativeness of the available evidence. Historical baseline adequacy was evaluated based on the representativeness and ecological plausibility of available data rather than sample size alone. The literature-derived historical baseline was selected for hard coral cover and branching coral ratio because it provided larger sample sizes and observation closer to the reference period, before the major bleaching events of the mid and late 1990s. Monitoring-derived maxima were generally based on fewer sites and more recent observation, which may already reflect degraded reef conditions. The monitoring-derived maximum-values approach was selected for the algae-coral ratio because historical algal records were sparse and differed in how algal groups were reported, whereas the harmonised monitoring data allowed the ratio to be calculated consistently. Where both approaches were available, their estimates are presented for comparison in Tables A6-A8.

Table A6. Comparison of initial hard coral cover estimates for each ecoregion using literature-derived historical baseline approach (Method 1) and long-term monitoring maxima (Method 2). Method 1 was selected for **hard coral cover** assessment. Values are percentages; n = number of sites.

Ecoregion	Baseline method	Mean	Std. dev	Min value	Max value	n
Western Arabian Sea – South	Historical published data	68.3	NA	68.3	68.3	1
Western Arabian	Long-term monitoring	-	-	-	-	-

Ecoregion	Baseline method		Mean	Std. dev	Min value	Max value	n
Sea – South	sites						
Western Arabian Sea – North	Historical data	published	-	-	-	-	-
Western Arabian Sea – North	Long-term sites	monitoring	-	-	-	-	-
Gulf of Oman	Historical data	published	70.2	19.0	47.5	99.5	6
Gulf of Oman	Long-term sites	monitoring	54.4	19.0	14.6	67.1	7
Arabian (Persian) Gulf – Northeast	Historical data	published	85.7	13.2	76.3	95.0	2
Arabian (Persian) Gulf – Northeast	Long-term sites	monitoring	73.4	NA	73.4	73.4	1
Arabian (Persian) Gulf – Inner	Historical data	published	33.8	14.1	5.0	67.3	37
Arabian (Persian) Gulf – Inner	Long-term sites	monitoring	29.2	13.9	13.3	39.3	3
Arabian (Persian) Gulf – Southeast	Historical data	published	42.9	23.3	2.0	90.0	19
Arabian (Persian) Gulf – Southeast	Long-term sites	monitoring	41.7	20.4	19.2	65.7	7

Note: SD could not be estimated where only one baseline site was available. For simulation, missing SD values were replaced by the mean SD estimated across the other ecoregions, and zero was used as the logical lower bound for hard coral cover.

Table A7. Comparison of initial branching coral ratio estimates for each ecoregion using the literature-derived historical baseline approach (Method 1) and long-term monitoring sites (Method 2). Method 1 was selected for **branching coral ratio** assessment. Values are ratios; n = number of sites.

Ecoregion	Baseline method		Mean	Std. dev	Min value	Max value	n
Western Arabian Sea – South	Historical data	published	0.80	NA	0.80	0.80	1
Western Arabian Sea – South	Long-term sites	monitoring	-	-	-	-	-
Western Arabian Sea – North	Historical data	published	-	-	-	-	-
Western Arabian Sea – North	Long-term sites	monitoring	-	-	-	-	-
Gulf of Oman	Historical data	published	0.83	0.12	0.70	0.99	6
Gulf of Oman	Long-term sites	monitoring	0.34	0.29	0.05	0.77	7
Arabian (Persian) Gulf – Northeast	Historical data	published	0.78	NA	0.78	0.78	1
Arabian (Persian) Gulf – Northeast	Long-term sites	monitoring	0.52	NA	0.52	0.52	1
Arabian (Persian) Gulf – Inner	Historical data	published	0.28	0.32	0.00	0.89	14
Arabian (Persian) Gulf – Inner	Long-term sites	monitoring	0.33	0.21	0.09	0.48	3
Arabian (Persian) Gulf – Southeast	Historical data	published	0.76	0.27	0.00	1.00	13
Arabian (Persian) Gulf – Southeast	Long-term sites	monitoring	0.04	0.03	0.00	0.07	7

Note: SD could not be estimated where only one baseline site was available. For selected baselines with missing or zero variance, SD estimated from the available ecoregional baselines distributions and logical bounds of 0-1 were used in the simulation.

Table A8. Comparison of initial algae-coral ratio estimates for each ecoregion using the literature-derived historical baseline approach (Method 1) and long-term monitoring sites (Method 2). Method 2 was selected for **algae-coral ratio** assessment. Values are ratios; n = number of sites.

Ecoregion	Baseline method	Mean	Std. dev	Min value	Max value	n
Western Arabian Sea – South	Historical published data	0.67	NA	0.67	0.67	1
Western Arabian Sea – South	Long-term monitoring sites	-	-	-	-	-
Western Arabian Sea – North	Historical published data	-	-	-	-	-
Western Arabian Sea – North	Long-term monitoring sites	-	-	-	-	-
Gulf of Oman	Historical published data	0.22	NA	0.22	0.22	1
Gulf of Oman	Long-term monitoring sites	0.14	0.26	0.01	0.74	7
Arabian (Persian) Gulf – Northeast	Historical published data	0.13	NA	0.13	0.13	1
Arabian (Persian) Gulf – Northeast	Long-term monitoring sites	0.10	NA	0.10	0.10	1
Arabian (Persian) Gulf – Inner	Historical published data	0.70	0.19	0.55	0.95	4
Arabian (Persian) Gulf – Inner	Long-term monitoring sites	0.18	0.30	0.00	0.53	3
Arabian (Persian) Gulf – Southeast	Historical published data	0.56	0.56	0.17	0.96	2
Arabian (Persian) Gulf – Southeast	Long-term monitoring sites	0.13	0.25	0.00	0.70	7

Note: SD could not be estimated where only one baseline site was available. For selected baselines with missing or zero variance, SD estimated from the available ecoregional baselines distributions and logical bounds of 0-1 were used in the simulation.

Collapse thresholds

Collapse thresholds were defined for each indicator to represent the degradation point at which ecosystem function or identity is completely lost, and the ecosystem is fundamentally changed.

For benthic indicators, thresholds reflect a transformation in ecosystem state from a coral-dominated reef to a degraded community characterised by reduced hard coral cover, increased algal dominance, and loss of structurally complex branching corals. Thresholds were based on **published studies, empirical observations and expert judgment**, and were applied **consistently** across all ecoregions (Bland et al., 2017; Obura et al., 2021).

For hard coral cover, a threshold of **5%** was applied, representing a significantly low abundance of the keystone taxa. This was selected as a conservative collapse threshold relative to the approximate 10% hard coral cover considered necessary to maintain positive carbonate accretion on a reef (Perry et al. 2013).

For the algae-coral ratio, a threshold of **0.833** (i.e. algae cover five times greater than coral cover) was used, indicating a persistent shift towards algal dominance where recovery to a coral-dominated state becomes unlikely.

For the branching coral ratio, a threshold of 0.05 was applied, representing a coral community in which branching corals comprised no more than 5% of total hard coral cover. This threshold was selected through expert elicitation to represent a state in which branching corals no longer make a meaningful contribution to reef structure or habitat complexity, reflecting the near-complete loss of this functionally important growth form. The threshold is considered appropriate for the RSA, where branching *Acropora*, *Pocillopora* and *Stylophora* have historically been major framework-building taxa in most of the ecoregions but have undergone widespread declines following successive marine heatwaves.

Calculating relative severity of decline

Relative severity of decline was calculated for each site with current data using the formula:

relative severity of decline (%) =

Uncertainty in initial conditions was incorporated using a simulation approach. For each ecoregion and indicator, initial values were represented as a truncated normal distribution defined by the estimated mean, standard deviation, and specified bounds. For hard coral cover, the lower bound was set to zero and the observed maximum was used as the upper bound. For ratio indicators with missing or zero variance, the standard deviation was estimated from the available ecoregional baselines and the logical bounds of 0 and 1 were applied. Initial values were randomly sampled from this ecoregional distribution and assigned to each site.

The highest risk category was determined from the decline-extent matrix (Fig A1), with the ecosystem extent calculated as the proportion of sites exceeding decline thresholds ($\geq 20\%$, $\geq 30\%$, $\geq 40\%$, $\geq 50\%$, $\geq 70\%$, $\geq 80\%$, and 100% decline). This process was repeated **1,000** times, and each time the resulting highest risk category for the iteration was recorded. To determine the final risk category for each indicator, the distribution of outcomes across all iterations was considered. Where $\geq 80\%$ of iterations produced the same category, this was assigned as the final status. When a dominant result was not returned, an appropriate category or range of categories was applied, e.g. if 50% of iterations were LC, and 50% VU, then the overall risk was NT.

The analysis assumed that monitoring sites broadly reflect conditions across the entire ecoregion. Where spatial coverage was uneven or limited, we assessed whether observed patterns were representative of the unsampled areas based on the distribution of pressures and environmental conditions. If the available data were considered insufficient to reliably characterise ecosystem-wide patterns, the ecoregion was classified as *Data Deficient*.

Determining final risk class for Criterion D

The overall risk category for Criterion D for each ecoregion was determined by integrating results across all indicators using a stepwise approach, following previous coral reef RLE assessments.

Indicators were evaluated in sequence according to their ecological role and interactions:

1. Hard corals (reef engineers)
2. Branching corals (structural complexity)

3. Algae (competitive dynamics)

The assessment used hard coral cover as the initial classification for each ecoregion. The remaining indicators (branching coral ratio and algae-coral ratio) were then incorporated sequentially using the IUCN RLE stepwise aggregation approach. Where a subsequent indicator was assigned a higher risk category than the cumulative classification to that point, the overall category increased by a single level, irrespective of the magnitude of the difference between categories. Indicators assigned to the same or lower risk category did not alter the cumulative classification.. This approach ensures that hard coral cover, as the foundational component of reef ecosystems, had the greatest influence on the final classification, while still accounting for changes in coral and benthic community composition and benthic structure. It also prevented the overall assessment from being disproportionately driven by any single secondary indicator.

Overall risk status

Once all applicable RLE criteria and subcriteria had been assessed, the overall risk status for coral reefs in each ecoregion was determined. A precautionary approach, consistent with the principles of the Red List of Ecosystems framework was applied whereby the final classification reflected the most severe risk category assigned across all evaluated criteria (Figure A2). This approach ensures that **any severe risk** which may drive collapse is not diluted or overlooked in the final assessment.

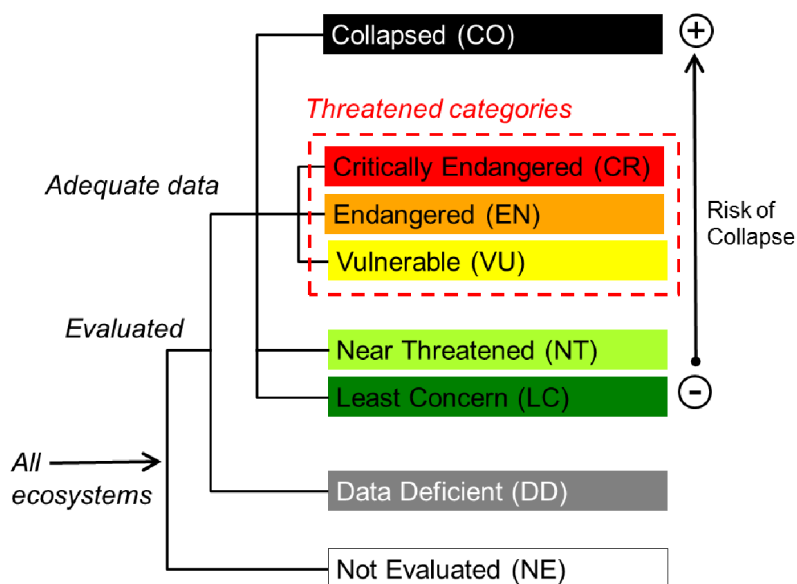


Figure A2. IUCN RLE classification framework, showing the relationship between data availability, evaluation status and risk of ecosystem collapse. CR, EN and VU constitute the threatened categories. CO = Collapsed; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated

11.3. Discussion

Coral reef ecosystems across the ROPME Sea Area face elevated collapse risk, but their current condition, disturbance histories and principal threats differ considerably. The Inner and

Southeast Gulf show the strongest evidence of historical degradation, including substantial declines in hard coral cover and branching corals. The Gulf of Oman and Northeast Gulf retain comparatively better ecosystem condition, while long-term ecological change remains less certain in the two Western Arabian Sea ecoregions because of limited historical and monitoring data. Despite these differences, marine heatwaves are an increasing threat across the region and are expected to become a major driver of collapse risk in most ecoregions. Their effects are compounded by persistent local pressures, including coastal development, dredging, pollution and overfishing.

The greater historical degradation observed in the Inner and Southeast Gulf is consistent with their long history of exposure to extreme environmental conditions. Corals in the Arabian (Persian) Gulf are among the most thermally tolerant in the world, but they also live very close to their physiological limits. Repeated mass bleaching events, particularly since the mid-1990s, have caused extensive mortality of branching *Acropora* and progressively reduced reef complexity, with recovery increasingly dominated by stress-tolerant massive and encrusting corals in this ecoregion (Burt et al., 2011; Burt & Paparella, 2024; Riegl et al., 2018; Sheppard & Loughland, 2002). These findings highlight that exceptional thermal tolerance alone is insufficient to ensure long-term ecosystem persistence, particularly when the frequency of thermal disturbances exceeds the time required for recovery.

The Gulf of Oman presents a different pattern. Compared with the Arabian (Persian) Gulf, its reefs have historically experienced lower thermal stress owing to more benign oceanic conditions and the influence of seasonal upwelling, but they are exposed to a different range of disturbances, including tropical cyclones, harmful algal blooms and crown-of-thorns starfish outbreaks (Bauman et al., 2010; Burt et al., 2016; Richlen et al., 2010). Coral cover recovered during the 2010s following some of these disturbances but declined again after the sequence of marine heatwaves in 2021 and later (Burt et al., 2026). Although this ecoregion currently shows less historical degradation than the Inner and Southeast Gulf, recent bleaching events suggest that the relative protection previously afforded by cooler oceanographic conditions may be diminishing as the region continues to warm.

The Western Arabian Sea ecoregions represent a different ecological setting from the rest of the ROPME Sea Area. Unlike the Arabian (Persian) Gulf and much of the Gulf of Oman, these reefs are strongly influenced by the southwest monsoon and seasonal upwelling, resulting in naturally cooler, nutrient-rich water in summer and distinctive coral-macroalgal communities (Glynn, 1993; Claereboudt, 2019). These environmental conditions have historically reduced exposure to severe thermal stress compared with other parts of the ROPME region, but they also indicate that ecological responses observed elsewhere in the region cannot necessarily be extrapolated to the western Arabian Sea. The best available validated reef-extent layer indicates that both ecoregions have restricted geographic distributions, creating additional vulnerability because localised disturbances or relatively small losses of reef area could affect a substantial proportion of either ecoregion. For Western Arabian Sea – North, regional survey evidence and expert review indicate that the mapped layer adequately represents the principal reef areas, although additional very low-cover coral communities may occur on rocky substrates. Its restricted distribution and continuing exposure to fishing and abandoned fishing gear, aquaculture development, sea-level

rise, and storm and cyclone damage support its Critically Endangered classification under B1. Interpretation is further constrained by limited historical observations and long-term monitoring, particularly for biotic change in both ecoregions and thermal responses in Western Arabian Sea – North (Burt et al., 2026).

The regional patterns identified by this assessment are broadly consistent with the recent GCRMN regional synthesis. Burt et al. (2026) reported that sea-surface temperature across ROPME coral reefs increased by approximately 0.5°C between 1985 and 2025 and that severe heat stress has occurred annually since 2020, affecting an increasing proportion of reefs. Their analysis also documented a shift from bleaching events separated by periods of partial recovery to successive disturbances in 2017, 2021, 2023 and 2024. This shortening of recovery intervals is particularly important because even the exceptionally thermally tolerant coral communities of the region require time for growth, recruitment and the reestablishment of structurally complex assemblages. Together, these observations support the high collapse risk associated with projected changes under subcriterion C2, where increasingly frequent marine heatwaves are expected to outpace the recovery capacity of reef-building corals. Fine-scale differences in exposure and coral response may allow some reefs to persist longer than the regional projections suggest, but do not alter the high regional risk associated with increasing marine heatwaves (Ben-Romdhane et al. 2018).

These regional patterns are broadly consistent with coral reef RLE assessments conducted elsewhere. As in the Western Indian Ocean (Obura et al., 2022), the risk associated with projected climate change emerged as the dominant driver of overall risk, while results based on historical declines and present conditions reflected sub-regional differences in disturbance history and local pressures. Unlike the Western Indian Ocean assessment, here restricted geographic distribution played a greater role in determining overall risk for the Western Arabian Sea – North, illustrating how the relative importance of individual RLE criteria can vary among ecoregions.

Several limitations should be considered when interpreting this assessment. Monitoring effort remains uneven across the ROPME Sea Area, with most long-term observations concentrated in the Arabian (Persian) Gulf and the Gulf of Oman (Burt et al., 2026). In addition, many monitoring sites have only been surveyed once, limiting the ability to distinguish long-term ecological change from short-term variability. These gaps constrained the assessment of some criteria and contributed to Data Deficient classifications where available information was considered insufficient to represent ecosystem-wide change. Additional uncertainty arises from the indicators used to assess ecosystem degradation. Criterion A relied on changes in the condition of reef sites as a proxy for changes in ecosystem extent because comparable historical habitat maps were unavailable. Criterion C depends on assumptions regarding the relationship between thermal stress, bleaching and mortality, while Criterion D was limited to a small number of benthic indicators. Limited spatial replication of some historical baselines also increases uncertainty in ecoregional estimates of biotic change. Consequently, important aspects of ecosystem condition, including coral recruitment, structural complexity, carbonate budgets and key fish functional groups, which are known to be important in this region (e.g. AlMealla et al., 2023; Bauman et al., 2014; Hoey et al., 2016), could not be evaluated consistently across the region.

Despite these uncertainties, the broad agreement between this assessment and other recent regional syntheses strengthens the conclusion that coral reefs across the ROPME Sea Area are undergoing a long-term decline in recovery capacity as marine heatwaves become more frequent and local pressures overlay these impacts. This highlights the importance of continued regional monitoring and future reassessments to improve understanding of ecosystem responses to climate change and reduce remaining sources of uncertainty.

Supplementary Tables

Supplementary Table S1. Published sources used to establish historical baselines for the Criterion D indicators.

Historical source	Ecoregion(s) informed	Criterion D indicator(s) informed
Al-Abdulkader, K. A., Loughland, R. A., & Qurban, M. A. (2019). Ecosystems and biodiversity of the Arabian Gulf. <i>Saudi Arabian waters: fifty years of scientific research</i> .	Arabian (Persian) Gulf - Inner	Hard coral cover; branching coral
Alhazeem, S. H., Burt, J. A., Alsaffar, A. H., Chen, W., & Al-Kandari, M. A. (2017). Long-term coral community stability in a disturbed marginal reef in Kuwait. <i>Journal of Water Resources and Ocean Science</i> , 6(6), 85-89.	Arabian (Persian) Gulf - Inner	Hard coral cover; branching coral; algae
Al-Ansi, M. A., & Al-Khayat, J. A. (1999). Preliminary study on coral reef and its associated biota in Qatari waters, Arabian Gulf. <i>Qatar University Science Journal</i> , 19, 294-311.	Arabian (Persian) Gulf - Southeast	Hard coral cover; branching coral; algae
Benzoni, F., Pichon, M., Alhazeem, S., & Galli, P. (2006). The coral reefs of the Northern Arabian Gulf: stability over time in extreme environmental conditions?. In <i>Proceedings of 10th International Coral Reef Symposium</i> (pp. 969-975).	Arabian (Persian) Gulf - Inner	Hard coral cover; branching coral; algae
Downing, N., & Roberts, C. (1993). Has the Gulf War affected coral reefs of the northwestern Gulf?. <i>Marine Pollution Bulletin</i> , 27, 149-156.	Arabian (Persian) Gulf - Inner	Hard coral cover
Glynn, P. (1993). Monsoonal upwelling and episodic Acanthaster predation as probable controls of coral reef distribution and community structure in Oman, Indian Ocean. <i>Atoll Research Bulletin</i> .	Arabian (Persian) Gulf - Northeast; Gulf of Oman; Western Arabian Sea - South	Hard coral cover; branching coral; algae
Kavousi, J., Seyfabadi, J., Rezai, H., & Fenner, D. (2011). Coral reefs and communities of Qeshm Island, the Persian Gulf. <i>Zool Stud</i> , 50(3), 276-283.	Arabian (Persian) Gulf - Northeast	Hard coral cover; branching coral; algae
McCain, J. C., Tarr, A. B., Carpenter, K. E., & Coles, S. L. (1984). Marine ecology of Saudi Arabia. A survey of coral reefs in the Northern Area, Arabian Gulf, Saudi Arabia. <i>Fauna of Saudi Arabia</i> 6: 102-126.	Arabian (Persian) Gulf - Inner	Hard coral cover; branching coral; algae
Moradi, M., Malekzadeh-Viayeh, R., & Eshaghi-Rad, J. (2014). Biodiversity of scleractinian corals in the reefs of Qeshm and Larak Islands of the Persian Gulf, in association with environmental variables. <i>Journal of the Marine Biological Association of the United Kingdom</i> , 94(5), 907-916.	Arabian (Persian) Gulf - Northeast	Hard coral cover; branching coral; algae
Purkis, S. J., & Riegl, B. (2005). Spatial and temporal dynamics of Arabian Gulf coral assemblages quantified from remote-sensing and in situ monitoring data. <i>Marine Ecology Progress Series</i> , 287, 99-113.	Arabian (Persian) Gulf - Southeast	Hard coral cover; branching coral; algae
Rezai, H., Samimi, K., Kabiri, K., Kamrani, E., Jalili, M., & Mokhtari, M. (2010). Distribution and abundance of the corals around Hengam and Farurgan islands, the Persian Gulf. <i>Journal of the Persian Gulf</i> , 1(1), 7-16.	Arabian (Persian) Gulf - Northeast	Hard coral cover; branching coral; algae
Salm, R. V., Jensen, R. A., & Papastavrou, V. A. (1993). Marine fauna of Oman: cetaceans, turtles, seabirds and shallow water corals.	Gulf of Oman	Hard coral cover
Salm, R. V. (1993). Coral reefs of the Sultanate of Oman. <i>Atoll</i>	Arabian (Persian) Gulf -	Hard coral cover;

Historical source	Ecoregion(s) informed	Criterion D indicator(s) informed
<i>Research Bulletin</i> , 380, 1-85.	Northeast; Gulf of Oman; Western Arabian Sea-South	branching coral
Sheppard, C. R. C., & Salm, R. V. (1988). Reef and coral communities of Oman, with a description of a new coral species (Order Scleractinia, genus <i>Acanthastrea</i>). <i>Journal of Natural History</i> , 22(1), 263-279.	Arabian (Persian) Gulf - Northeast; Gulf of Oman; Western Arabian Sea-South	Hard coral cover; branching coral; algae
Smith, G. B., & Saleh, M. A. (1987). Abundance and bathymetric distribution of Bahrain (Arabian Gulf) reef ichthyofaunas. <i>Estuarine, Coastal and Shelf Science</i> , 24(3), 425-431.	Arabian (Persian) Gulf - Southeast	Hard coral cover; branching coral
Vogt, H. (1994). Status of the coral reefs after the Gulf War. <i>The status of coastal and marine habitats two years after the Gulf War oil spill</i> . <i>Courier Forschungsinstitut Senckenberg</i> , 166, 61-66.	Arabian (Persian) Gulf - Inner	Hard coral cover
Vogt, I. P. (1995). Coral reefs in Saudi Arabia: 3.5 years after the Gulf War oil spill. <i>Coral Reefs</i> , 14(4), 271-273.	Arabian (Persian) Gulf - Inner	Hard coral cover
Vousden, D. H. (1987). The Bahrain marine habitat survey: a study of the marine habitats in the waters of Bahrain and their relationship to physical, chemical and anthropogenic influences. <i>ROPME, Kuwait</i> .	Arabian (Persian) Gulf - Southeast	Hard coral cover; branching coral; algae

Criterion C – Environmental Degradation: supplementary figures

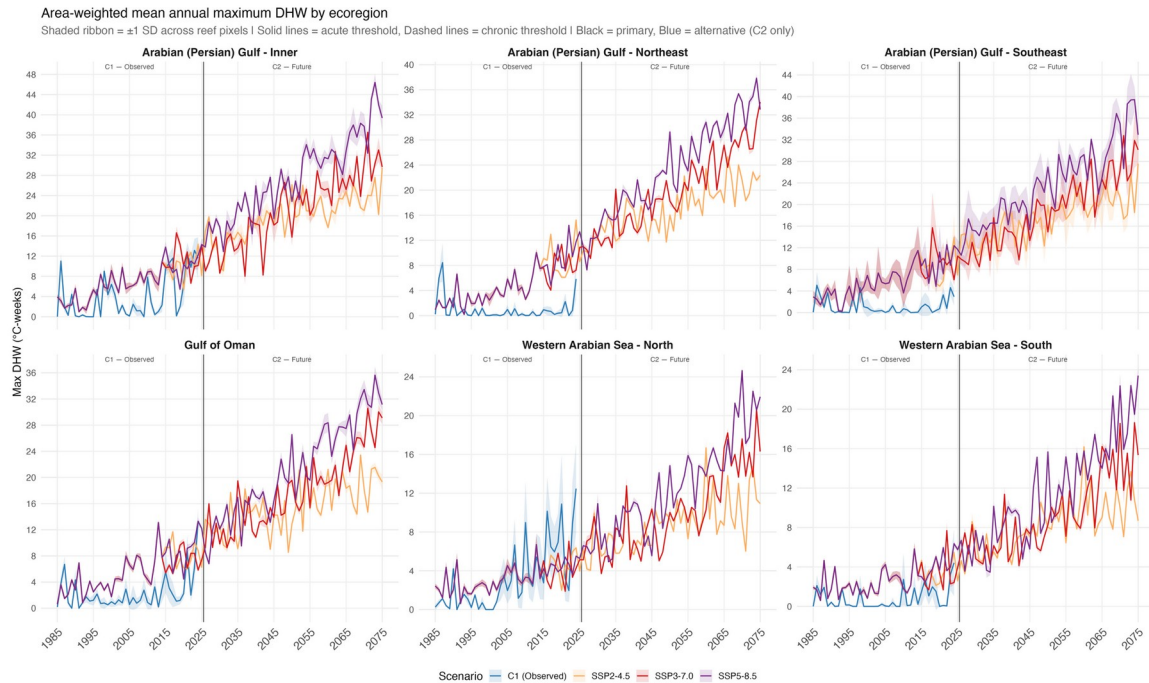


Figure S1. Annual maximum Degree Heating Weeks (DHW) averaged across coral reefs within each ecoregion from 1985-2075 for four trajectories: observed data used to assess sub-criterion C1 from 1985-2025 (blue line), and projections under three Shared Socioeconomic Pathways — SSP2-4.5 (orange), SSP3-7.0 (red), and SSP5-8.5 (purple). Shaded ribbons represent ± 1 SD in DHW across reef pixels within each ecoregion, reflecting spatial variability in thermal exposure. Horizontal lines show ecoregion-specific DHW thresholds at various points in time corresponding to severe bleaching events (chronic stress pathway; dashed lines) and severe mortality events (acute stress pathway; solid lines). Black lines indicate primary thresholds, and blue lines indicate alternative thresholds (C2 period only, 2026–2075). The vertical grey line marks the boundary between the observed (C1 - 1985-2025) and projected (C2 - 2026-2075) assessment periods.

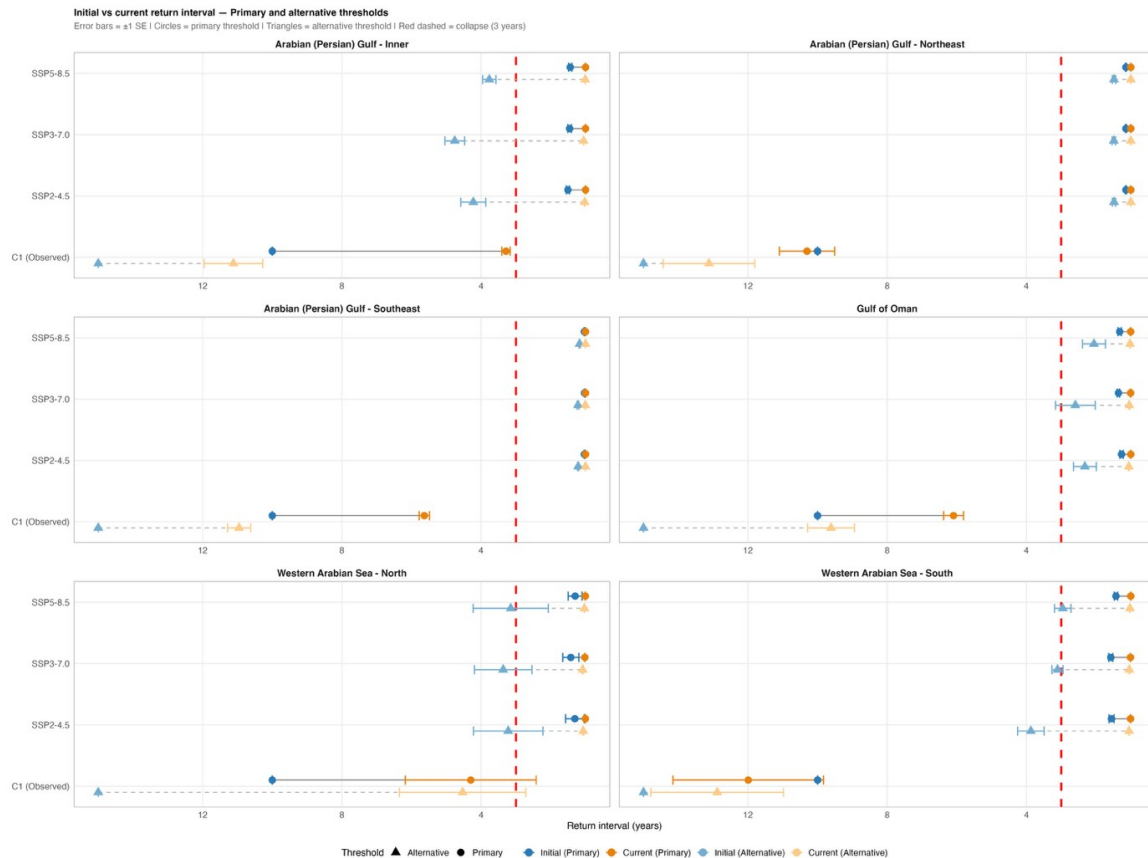


Figure S2. Change in the average return interval between severe bleaching events (years) for each ecoregion (x-axis), comparing initial conditions (blue) to current or projected future conditions (orange) across four trajectories (y-axis): observed data (C1) and projections under SSP2-4.5, SSP3-7.0, and SSP5-8.5. Connecting lines indicate the direction and magnitude of change between initial and current conditions. Return intervals were estimated for the chronic pathway by fitting a binomial regression model to the binary bleaching event time series for each reef pixel, with values representing the shortest return interval identified over each assessment period (C1: 1985–2025; C2: 2026–2075). Results are shown for both primary (filled circles) and alternative (filled triangles) DHW thresholds. For C1, initial conditions are assumed to reflect historical disturbance regimes prior to the satellite record, corresponding to a return interval of 10 years (primary threshold) and 15 years (alternative threshold). For C2, initial conditions are calculated from projected DHW data over 1996–2025 using the same probabilistic model. Error bars represent ± 1 SE across reef pixels within each ecoregion. The red dashed vertical line marks the collapse threshold of a 3-year return interval, below which disturbance frequency is considered sufficient to prevent meaningful coral recovery and drive progressive ecosystem degradation. Note that the x-axis is reversed such that movement from left to right represents a shortening return interval and worsening conditions.

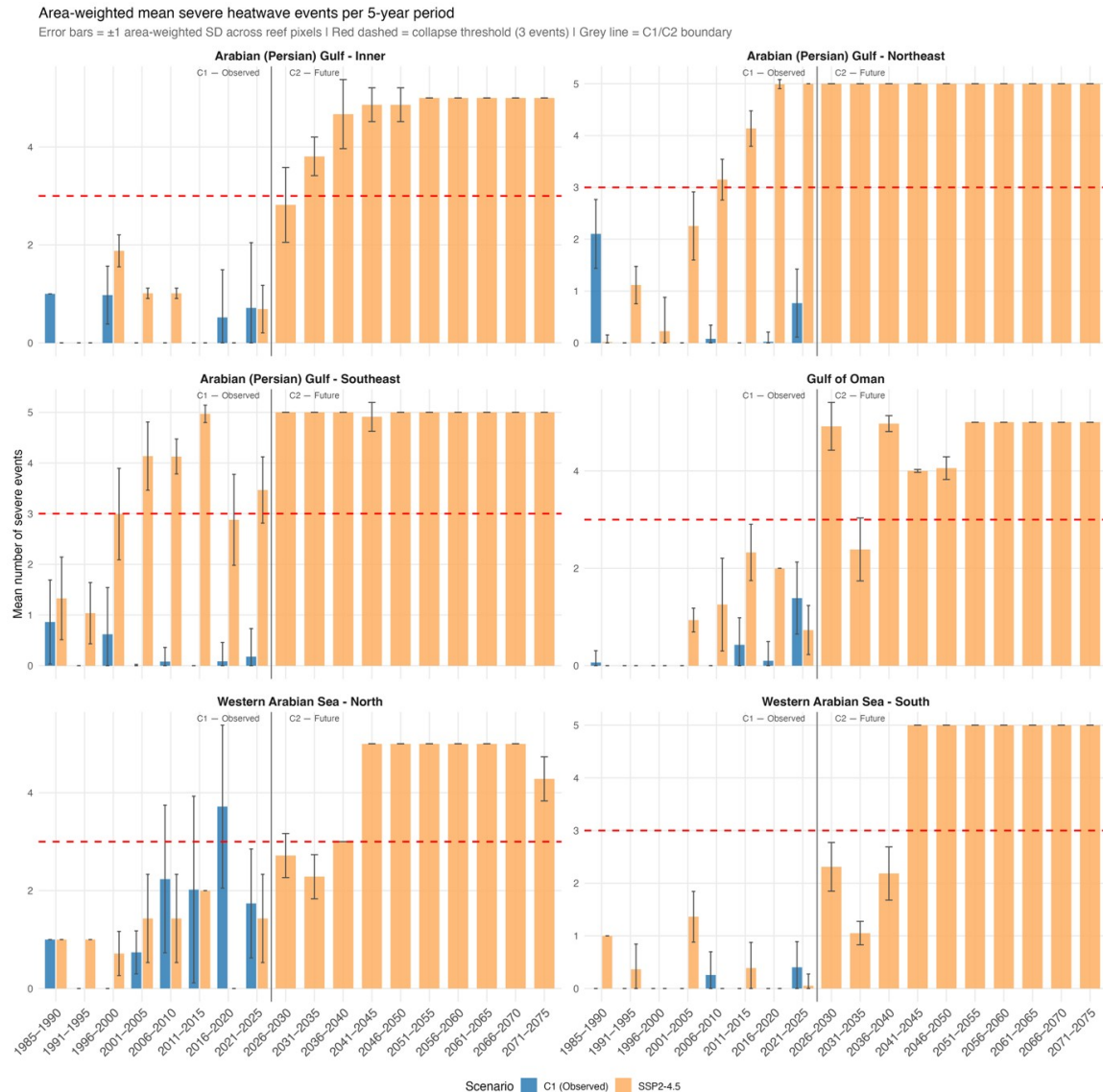


Figure S3. Mean number of severe mortality events per 5-year period, averaged across coral reef pixels within each ecoregion, under two trajectories: observed data used to assess sub-criterion C1 (blue bars, 1985–2025) and projections under SSP2-4.5 (orange bars, 1985–2075). Severe mortality events are defined as years in which annual maximum DHW exceeded ecoregion-specific acute stress thresholds associated with widespread coral mortality. Error bars represent ± 1 SD across reef pixels within each ecoregion, reflecting spatial variability in the frequency of severe thermal exposure. The red dashed horizontal line indicates the collapse threshold of 3 severe mortality events within a 5-year window. The vertical grey line marks the boundary between the observed (C1, 1985–2025) and projected (C2, 2026–2075) assessment periods.

Appendices: Ecoregion Factsheets

Western Arabian Sea – South (CR)

Spatial distribution

The Western Arabian Sea – South ecoregion extends along the southern coast of Oman and contains an estimated 5.61 km² of coral habitat (Figure 1). It forms the southern part of the original MEOW Western Arabian Sea ecoregion and was delineated to capture the section most strongly influenced by seasonal monsoon-driven upwelling. Coral communities are geographically restricted and occur mainly as marginal coral carpets, with limited true reef-framework.

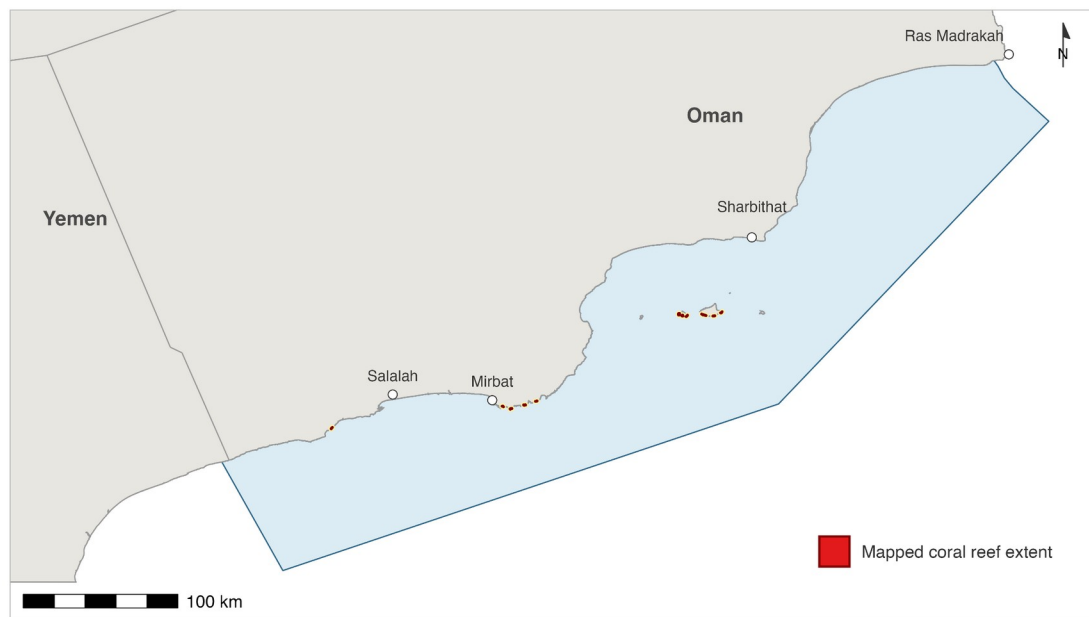


Figure 1. Distribution of the mapped coral reef habitat (red) in the Western Arabian Sea – South ecoregion (blue).

Ecosystem description

Coral communities of the Western Arabian Sea – South form a distinct ecoregion shaped by the intense seasonal influence of the southwest monsoon. Summer upwelling brings cold, nutrient-rich water to the Dhofar coast, occasionally lowering sea-surface temperatures to approximately 16°-19°C and supporting high biological productivity. Heavy wave exposure and the seasonal shoaling of the Oxygen Minimum Zone further distinguish this environment from the Gulf of Oman and the Arabian (Persian) Gulf. Coral habitat occurs primarily as marginal, low-relief coral carpets rather than extensive framework-building reefs (Figure 2). These coral communities coexist with seasonally abundant canopy-forming macroalgae, particularly *Nizamuddinina zanardinii*. Despite limited reef development, the Western Arabian Sea supports the highest coral species richness in the ROPME Sea Area, with more than 140 coral species recorded across the two Western Arabian Sea ecoregions. Its reef-associated fauna includes regionally distinctive species such as the Dhofar parrotfish (*Scarus zufar*).



Figure 2. Low-relief coral carpet characteristic of the Western Arabian Sea – South ecoregion, Dhofar, Oman, 2024 (photo: Christophe Chellapermal)

The principal pressures include possible changes in the timing and intensity of monsoon-driven upwelling, fishing and ghost fishing, acute storm damage from tropical cyclones, and localised coastal development. The combination of restricted distribution, strong seasonal environmental variability and distinctive coral-macroalgal dynamics separates this ecoregion from the Western Arabian Sea – North.

Key ecosystem characteristics and threats

Ecoregion	Key Biotic	Key Abiotic	Key Threats
Western Arabian Sea – South	Predominantly marginal coral communities; seasonal macroalgal-coral assemblages (<i>Nizamuddinia zanardinii</i>); geographically restricted Dhofar parrotfish (<i>Scarus zufar</i>).	Intense seasonal southwest monsoon upwelling; high nutrient availability and primary productivity; heavy wave action; shoaling Oxygen Minimum Zone (OMZ).	Changes in the Indian Ocean monsoon/upwelling regime; fishing pressure (including ghost fishing); acute storm damage (tropical cyclones); localised coastal development.

Key values

Proportion of assessed reef sites falling below the 5% hard coral cover collapse threshold	Distribution (Criterion B)		Observed thermal stress, 1985-2025 (Subcriterion C1)	Biotic Indicator Values (Criterion D)		
	EOO (km ²)	AOO		Indicator	Baseline	Current
9.1% of 11 sites	4,153	9 occupied 10x10km grid cells	Repeated severe events over 30-year periods: NT; clustering of severe events within five-year windows: LC	hard coral cover	68.3%* (n=1)	21.2% ± 7.2SD (n=11)
				branching coral ratio	0.80* (n=1)	0.13 ± 0.24 SD (n=10)
				algae-coral ratio	DD	DD

NT = Near Threatened; LC = Least Concern; DD = Data Deficient

* The historical baseline was represented by only one site and was insufficient to support an ecoregional assessment. Western Arabian Sea – South was therefore classified as Data Deficient under Criterion D.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Western Arabian Sea – South** was assessed as **Critically Endangered (CR)**. This classification was driven by projected thermal stress under subcriterion C2. When subcriterion C2 was considered separately, the highest category across A1, B, C1 and D1 was Endangered (EN), driven by the ecoregion's restricted geographic distribution under Criterion B. Limited historical and long-term monitoring data also resulted in a Data Deficient (DD) classification under Criterion D.

Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	EN	EN	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1975)	Future or any 50y period	Historical (1750)
	NT	CR	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1975)	Future or Any 50y period	Historical (1750)
	DD	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated.

Key findings and recommendations

- The ecoregion was classified as **Critically Endangered overall**, driven by the high risk associated with projected increases in marine heatwaves under subcriterion C2.
- Its restricted distribution resulted in an **Endangered** classification under Criterion B, making the ecoregion particularly vulnerable to local habitat loss.
- Based on observed thermal stress between 1985 and 2025, the ecoregion was classified as **Near Threatened** under subcriterion C1, while 9% of assessed reef sites had hard coral cover at or below the 5% collapse threshold.
- Insufficient historical and long-term ecological data resulted in a **Data Deficient** classification under Criterion D, preventing a robust assessment of long-term changes in reef condition.

Priority actions

- Strengthen long-term monitoring of coral cover, branching corals, algae, reef-fish communities, coral recruitment and juvenile survival.
- Identify and protect reefs showing resistance to or recovery from thermal stress.
- Reduce local pressures from fishing, abandoned fishing gear, coastal development and pollution.
- Improve understanding of how monsoon-driven upwelling influences reef condition, thermal exposure and recovery.
- Support broader action to limit climate change alongside local measures that strengthen reef resilience.

Western Arabian Sea – North (CR)

Spatial distribution

The Western Arabian Sea – North ecoregion extends along the central-eastern coast of Oman, from around Ras Madrasah in the south to Ras al Hadd in the north. Mapped coral reefs cover approximately 3.65 km² and are concentrated around Barr al Hikman and Masirah Island (Figure 1). The southern boundary marks the transition from the strongly upwelling-influenced coral communities of southern Oman, while the northern boundary reflects the shift towards the oceanographic and ecological conditions of the Gulf of Oman.



Figure 1. Distribution of the mapped coral reef habitat (red) in the Western Arabian Sea – North ecoregion (blue).

Ecosystem description

Reef development is generally limited, with coral communities occurring mainly as marginal reefs and low-relief coral veneers. Small, monospecific areas of *Montipora foliosa* occur at different locations across the ecoregion, including Masirah Island, but at Barr al Hikman the species forms extensive frameworks that are unusual within the wider region because of their scale (Figure 2).

Coral diversity is relatively high compared with the Arabian (Persian) Gulf, and the benthic communities include beds of macroalgae, particularly *Sargassum* and *Padina*. These communities are influenced by seasonal upwelling associated with the southwest monsoon. Although weaker than farther south in Dhofar, it brings cooler, nutrient-rich waters to the coast, supports high biological productivity and creates marked seasonal variation in sea temperature.



Figure 2. Coral and reef-fish communities at Masirah Island, Western Arabian Sea – North ecoregion, Oman, 2005. Left: *Montipora foliosa* colony. Right: diverse reef-fish assemblage (photos: Oli Taylor).

The main pressures include fishing and lost or abandoned fishing gear, expanding aquaculture and tourism, and acute storm and cyclone damage, particularly to the localised *Montipora foliosa* frameworks. Its reefs are also geographically restricted, which increases their sensitivity to local habitat loss and other disturbances. Long-term information on changes in coral condition, bleaching and recovery remains limited, making it difficult to establish how these communities respond to thermal stress. The combination of moderate seasonal upwelling, high coral diversity, seasonal macroalgal growth and the unusual reef frameworks at Barr al Hikman distinguishes this ecoregion from both the strongly upwelling-influenced reefs farther south and the reefs of the Gulf of Oman.

Key ecosystem characteristics and threats

Ecoregion	Key Biotic	Key Abiotic	Key Threats
Western Arabian Sea – North	Predominantly marginal reefs with localised monospecific <i>Montipora foliosa</i> reef frameworks; high coral species richness; seasonal <i>Sargassum</i> and <i>Padina</i> beds.	Moderate seasonal upwelling; high seasonal SST variability; high nutrient availability and primary productivity.	Changes in upwelling dynamics; fishing pressure (including ghost fishing); acute storm and cyclone damage; aquaculture expansion; emerging tourism pressure.

Key values

Proportion of assessed reef sites falling below the 5% hard coral cover collapse threshold	Distribution (Criterion B)		Observed thermal stress, 1985-2025 (Subcriterion C1)	Biotic Indicator Values (Criterion D)		
	EOO (km ²)	AOO		Indicator	Baseline	Current
0% of 3 sites	419	7 occupied 10x10km grid cells	NE: insufficient region-specific evidence to relate DHW exposure	hard coral cover	DD	47.5% ± 16.4SD (n=3)
				branching coral ratio	DD	DD

Proportion of assessed reef sites falling below the 5% hard coral cover collapse	Distribution (Criterion B)		Observed thermal stress, 1985-2025 (Subcriterion C1)	Biotic Indicator Values (Criterion D)		
	EOO (km ²)	AOO		Indicator	Baseline	Current
			reliably to bleaching or mortality	algae-coral ratio	DD	DD

NE = Not Evaluated; DD = Data Deficient

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Western Arabian Sea – North** was assessed as **Critically Endangered (CR)**. This classification was driven by the ecoregion's highly restricted geographic distribution under subcriterion B1. Criterion C was Not Evaluated because there was insufficient region-specific evidence to establish reliable relationships between thermal stress, bleaching and coral mortality. Limited historical and long-term monitoring data also resulted in a Data Deficient classification under Criterion D.

Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	CR	EN	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1975)	Future or any 50y period	Historical (1750)
	NE	NE	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1975)	Future or Any 50y period	Historical (1750)
	DD	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened;

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

Key findings and recommendations

- The ecoregion was classified as **Critically Endangered overall**, driven by its restricted geographic distribution under subcriterion B1.
- None of the assessed reef sites had hard coral cover at or below the 5% collapse threshold, resulting in a Least Concern classification under subcriterion A1.
- Criterion C was Not Evaluated because region-specific evidence linking thermal stress to bleaching and mortality was insufficient to establish reliable thresholds.

- Limited historical and long-term monitoring data resulted in a Data Deficient classification under Criterion D.
- Because reefs occupy a small area, local disturbances could affect a substantial proportion of the ecoregion.

Priority actions

- Expand long-term monitoring around Barr al Hikman, Masirah Island and the adjacent mainland coast, using consistent methods for coral cover, recruitment and juvenile survival, branching corals, algae and reef-fish communities.
- Document bleaching severity, coral mortality and recovery following thermal-stress events to establish region-specific thermal-stress thresholds.
- Reduce impacts from fishing and abandoned fishing gear, and ensure that aquaculture and tourism development avoid damage to reef areas.
- Prioritise protection of the unusual *Montipora foliosa* frameworks at Barr al Hikman because of their exceptional scale, ecological distinctiveness and restricted distribution.

Gulf of Oman (CR)

Spatial distribution

The Gulf of Oman ecoregion extends along the northern coast of Oman, the eastern coast of the United Arab Emirates and the southern coast of Iran, and contains an estimated 28.86 km² of coral habitat (Figure 1). It broadly follows the original MEOW Gulf of Oman ecoregion, with its northern boundary refined to reflect the transition in oceanographic and environmental conditions through the Strait of Hormuz.



Figure 1. Distribution of the mapped coral reef habitat (red) in the Gulf of Oman ecoregion (blue).

Ecosystem description

Coral reefs of the Gulf of Oman occur along the coasts of northern Oman, eastern United Arab Emirates and southern Iran, as well as around offshore islands, including the Daymaniyat Islands Nature Reserve. Reef development varies from marginal coral communities to fringing and patch reefs, with greater structural development in sheltered bays and around islands (Figure 2). Coral diversity is generally higher than in the Arabian (Persian) Gulf.

Environmental conditions are influenced by exchange with both the Arabian (Persian) Gulf and the Western Arabian Sea. Compared with the shallow Gulf, the deeper and more open waters of the Gulf of Oman experience less extreme salinity and temperature variability, although seasonal changes in circulation and productivity, including localised seasonal upwelling, remain important. This transitional setting supports diverse coral and fish communities but also exposes reefs to disturbances originating from adjacent marine systems.



Figure 2. Coral communities in the Daymaniyat Islands Nature Reserve, Gulf of Oman, Oman. Left: large *Porites* colony at Kharabah Island, with diver for scale, photographed in 2017. Right: *Pocillopora*-dominated community with macroalgal growth visible in the background at Kasmah Island, photographed in 2026 (photos: Paul Flandinette).

The main pressures include marine heatwaves, harmful algal blooms, crown-of-thorns starfish outbreaks, cyclones, coastal development, desalination discharge, pollution and fishing. These disturbances have caused substantial but spatially variable impacts, with some reefs showing greater resistance or recovery than others. The combination of relatively high coral diversity, varied reef development and strong environmental connectivity distinguishes this ecoregion from both the Arabian (Persian) Gulf and the monsoon-influenced reefs of the Western Arabian Sea.

Key ecosystem characteristics and threats

Ecoregion	Key Biotic	Key Abiotic	Key Threats
Gulf of Oman	Mixed true framework-building and marginal coral reefs; structurally complex <i>Acropora</i> and <i>Platygyra</i> coral assemblages; high biomass of commercially important reef fishes.	Oceanic salinities; seasonal upwelling along parts of the Iranian and Omani coasts; Ras Al Hadd oceanographic transition.	Marine heatwaves (bleaching); harmful algal blooms (HABs); crown-of-thorns starfish (COTS) outbreaks; tropical cyclones; fishing pressure; tourism-related anchor damage; localised coastal development and desalination discharges.

Key values

Proportion of assessed reef sites falling below the 5% hard coral cover collapse threshold	Distribution (Criterion B)		Observed thermal stress, 1985-2025 (Subcriterion C1)	Biotic Indicator Values (Criterion D)		
	EOO (km ²)	AOO		Indicator	Baseline	Current
3% of 29 sites	80,604	22 occupied 10x10km grid cells	Repeated severe events over 30-year periods: VU; clustering of severe events within five-year windows: VU	hard coral cover	70.2% ± 19.0 SD (n=6)	34.0% ± 18.2 SD (n=29)
				branching coral ratio	0.83 ± 0.12 SD (n=6)	0.17 ± 0.24 SD (n=29)
				algae-coral ratio	0.14 ± 0.26SD (n=7)	0.38 ± 0.27 SD (n=29)

VU = Vulnerable

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the **Gulf of Oman** was assessed as **Critically Endangered (CR)**. This classification was driven by projected thermal stress under subcriterion C2. The ecoregion was also classified as Endangered under Criterion D, reflecting declines in hard

coral cover and branching corals, while its restricted geographic distribution resulted in a Vulnerable classification under Criterion B.

Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	VU	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1975)	Future or any 50y period	Historical (1750)
	VU	CR	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1975)	Future or Any 50y period	Historical (1750)
	EN	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; DD = Data Deficient; LC = Least Concern; NE = Not Evaluated.

Key findings and recommendations

- The ecoregion was classified as **Critically Endangered overall**, driven by the high risk associated with projected thermal stress under subcriterion C2.
- Based on observed thermal stress between 1985 and 2025, the ecoregion was classified as Vulnerable under subcriterion C1, indicating that marine heatwaves already present a substantial risk.
- Three per cent of assessed reef sites had hard coral cover at or below the 5% collapse threshold, resulting in a Least Concern classification under subcriterion A1.
- Its restricted geographic distribution resulted in a Vulnerable classification under Criterion B.
- Evidence of declines in hard coral cover and branching corals resulted in an Endangered classification under Criterion D.

Priority actions

- Maintain and expand long-term monitoring across Oman, the United Arab Emirates and Iran, using consistent methods for coral cover, recruitment and juvenile survival, algae and reef-fish communities.
- Document bleaching, coral mortality and recovery following marine heatwaves to refine regional thermal-response thresholds.

- Identify and protect reefs that show resistance to or recovery from thermal stress.
- Reduce pressures from coastal development, desalination discharge, fishing, pollution and tourism-related anchoring, particularly around sensitive or heavily used reefs.
- Strengthen surveillance and rapid response for harmful algal blooms and crown-of-thorns starfish outbreaks.

Arabian (Persian) Gulf – Northeast (CR)

Spatial distribution

The Arabian (Persian) Gulf – Northeast ecoregion extends along the southern coast of Iran and the Musandam Peninsula of Oman and contains an estimated 59.34 km² of coral habitat (Figure 1). It forms a subdivision of the original MEOW Arabian (Persian) Gulf ecoregion and was delineated to represent the transition zone between the Gulf and the Gulf of Oman, characterised by distinct circulation, bathymetry and environmental conditions.

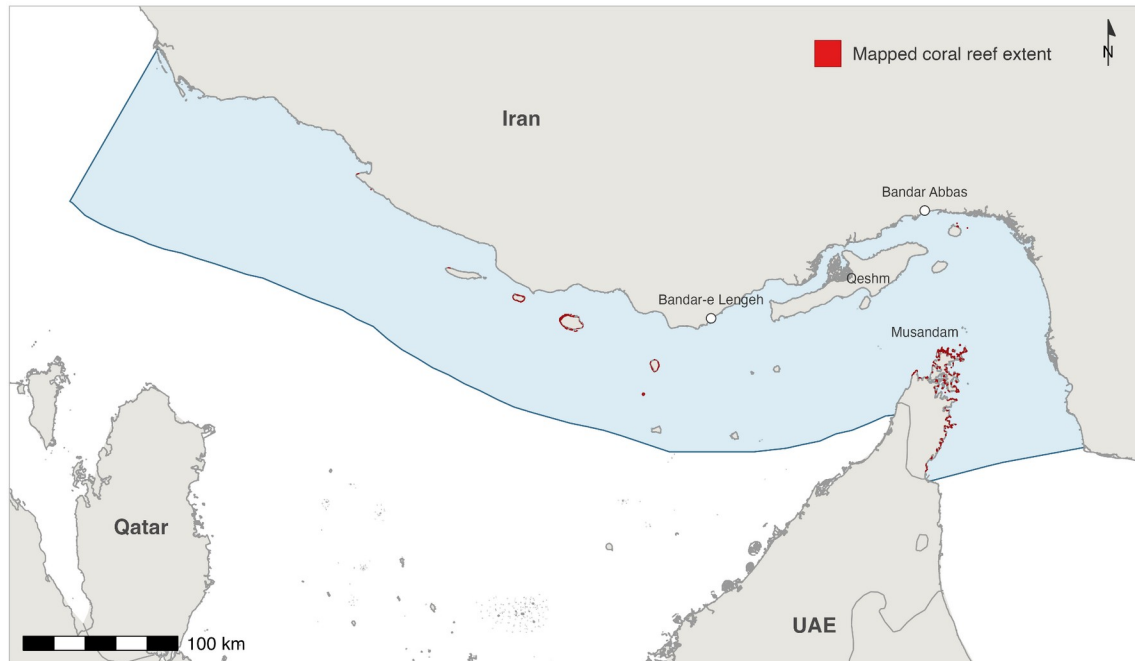


Figure 1. Distribution of the mapped coral reef habitat (red) in the Arabian (Persian) Gulf – Northeast ecoregion (blue).

Ecosystem description

Coral reefs of the Arabian (Persian) Gulf – Northeast occur along the Iranian coast and islands and around the Musandam Peninsula of Oman (Figure 2). Coral communities develop on rocky coastlines, around islands and within the fjord-like bays of Musandam, where steep coastal topography and limited shallow substrate shape the extent of reef development. Reef development ranges from structurally complex framework-building reefs to fringing coral communities, coral patches and low-relief veneers.

The ecoregion forms a transition between the Arabian (Persian) Gulf and the Gulf of Oman. Water exchange through the Strait of Hormuz produces stronger circulation and more moderate temperature and salinity conditions than those experienced farther inside the Gulf. These conditions support relatively diverse coral communities, although environmental conditions vary considerably between exposed coasts, islands and sheltered bays.



Figure 2. Structurally complex coral communities in the Arabian (Persian) Gulf – Northeast ecoregion. Left: branching *Acropora* assemblages in Musandam, Oman, 2022 (photo: Rebekka Pentti). Right: partially bleached tabular *Acropora* colonies at Kish Island, Iran, 2026 (photo: Saeed Parvin).

The main pressures include marine heatwaves, coastal development, shipping, pollution and fishing. Reefs near ports and heavily used coastal areas are particularly exposed to local disturbance, while the restricted distribution of suitable shallow habitat increases their sensitivity to habitat loss. The combination of strong water exchange, rocky and fjord-like habitats and transitional coral communities distinguishes this ecoregion from both the inner Gulf and the Gulf of Oman.

Key ecosystem characteristics and threats

Ecoregion	Key Biotic	Key Abiotic	Key Threats
Arabian (Persian) Gulf – Northeast	True reefs grading into marginal reefs; structurally complex coral assemblages transitioning to stress-tolerant Gulf communities; relatively high coral diversity compared to the southern Gulf.	Extreme seasonal SST; elevated salinity; large tidal range and periodic aerial exposure; oceanic water exchange through the Strait of Hormuz.	Coastal development and habitat loss; Harmful Algal Blooms (HABs); oil and wastewater pollution; tourism-related anchor damage.

Key values

Proportion of assessed reef sites falling below the 5% hard coral cover collapse threshold	Distribution (Criterion B)		Observed thermal stress, 1985-2025 (Subcriterion C1)	Biotic Indicator Values (Criterion D)		
	EOO (km ²)	AOO		Indicator	Baseline	Current
0% of 5 sites	43,783	31 occupied 10x10km grid cells	Repeated severe events over 30-year periods: LC; clustering of severe events within five-year windows: NT	hard coral cover	85.7% ± 13.2 SD (n=2)	50.2% ± 20.5 SD (n=5)
				branching coral ratio	0.78 (n=1)	0.21 ± 0.22 SD (n=5)
				algae-coral ratio	0.10 (n=1)	0.20 ± 0.19 SD (n=5)

NT = Near Threatened; LC = Least Concern

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the **Arabian (Persian) Gulf – Northeast** was assessed as **Critically Endangered (CR)**. This classification was driven by projected thermal

stress under subcriterion C2. The ecoregion was also classified as Vulnerable under Criteria B and D, reflecting its restricted geographic distribution and declines in branching coral abundance. Historical thermal stress under subcriterion C1 was assessed as Near Threatened.

Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	VU	VU	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1975)	Future or any 50y period	Historical (1750)
	NT	CR	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1975)	Future or Any 50y period	Historical (1750)
	VU	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened;

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

Key findings and recommendations

- The ecoregion was classified as **Critically Endangered overall**, driven by the high risk associated with projected thermal stress under subcriterion C2.
- None of the five assessed reef sites had hard coral cover at or below the 5% collapse threshold, resulting in a Least Concern classification under subcriterion A1.
- Based on observed thermal stress between 1985 and 2025, the ecoregion was classified as Near Threatened under subcriterion C1.
- Its restricted geographic distribution resulted in a Vulnerable classification under Criterion B.
- Criterion D was classified as Vulnerable, driven mainly by estimated declines in branching corals. This result should be interpreted cautiously because the historical baselines were based on very few sites.

Priority actions

- Expand long-term monitoring along the Iranian coast and around Musandam, using consistent methods for corals, algae and reef-fish communities.
- Document bleaching severity, coral mortality and recovery following marine heatwaves to improve understanding of thermal responses in this transitional ecoregion.

- Identify and protect reefs that retain high coral diversity, structural complexity or resistance to thermal stress.
- Reduce habitat degradation associated with coastal development, pollution and wastewater discharge.
- Strengthen controls on anchoring and other tourism-related damage, alongside surveillance for harmful algal blooms.

Arabian (Persian) Gulf – Inner (CR)

Spatial distribution

The Arabian (Persian) Gulf – Inner ecoregion extends across the northern and northwestern Gulf, including coastal and offshore waters of Iran, Iraq, Kuwait and Saudi Arabia, and contains an estimated 44.97 km² of coral habitat (Figure 1). It forms a subdivision of the original MEOW Arabian (Persian) Gulf ecoregion and was delineated to reflect restricted circulation, the influence of the Shatt al-Arab river system, and extreme seasonal variation in temperature and salinity.



Figure 1. Distribution of the mapped coral reef habitat (red) in the Arabian (Persian) Gulf – Inner ecoregion (blue).

Ecosystem description

Coral reefs of the Arabian (Persian) Gulf – Inner include true framework-building reefs around offshore islands together with extensive marginal reef systems along the coast (Figure 2). In Saudi waters, shallow communities are dominated by stress-tolerant massive corals, including *Porites*, *Platygyra*, *Dipsastraea* and *Cyphastrea*, while *Turbinaria* is common at greater depths. Remnant tabular *Acropora* persists on some offshore reefs. Despite the extreme environmental conditions, these reefs support diverse coral assemblages adapted to large seasonal fluctuations in temperature and salinity. High rates of bioerosion influence reef structure and carbonate balance, while the reefs provide important habitat for commercially valuable groupers and other reef-associated species.

Environmental conditions are shaped by the shallow, semi-enclosed nature of the Inner Gulf, where restricted circulation contributes to hypersalinity and pronounced seasonal variability.

Freshwater, sediment and nutrient inputs from the Shatt al-Arab create strong environmental gradients, particularly in the northern Inner Gulf. These gradients contribute to marked differences between turbid nearshore environments and clearer offshore waters where framework-building reefs occur.



Figure 2. Coral reef communities of the Arabian (Persian) Gulf – Inner ecoregion. Left: reef at Jana Island, Saudi Arabia, 2025 (photo: Goutham Sambath). Right: coral assemblage at Qaruh Island, Kuwait, 2025 (photo: Zaid Alnaser).

The main pressures include changes in the freshwater and sediment discharge from the Shatt al-Arab, particularly in the northern Inner Gulf, as well as desalination effluent and industrial pollution. Intensive fishing affects commercially important reef-fish populations, while anchoring by recreational vessels can cause direct physical damage to coral colonies and reef structure. These pressures act on reef communities already living close to their environmental limits, increasing their vulnerability to further disturbance.

Key ecosystem characteristics and threats

Ecoregion	Key Biotic	Key Abiotic	Key Threats
Arabian (Persian) Gulf – Inner	True framework-building reefs on offshore islands together with extensive marginal coastal reef systems; diverse coral assemblages adapted to extreme environmental conditions; high bioerosion rates; important commercial grouper habitats.	Hypersalinity; extreme seasonal temperature variability; restricted circulation; strong environmental gradients associated with the Shatt al Arab.	Marine heatwaves and mass bleaching; reduced freshwater and sediment discharge from Shatt al Arab; desalination effluent; industrial pollution; intensive fishing and abandoned fishing gear; physical damage from anchoring by recreational vessels.

Key values

Proportion of assessed reef sites falling below the 5% hard coral cover collapse threshold	Distribution (Criterion B)		Observed thermal stress, 1985-2025 (Subcriterion C1)	Biotic Indicator Values (Criterion D)		
	EOO (km ²)	AOO		Indicator	Baseline	Current
50% of 4 sites	31,289	30 occupied 10x10km grid cells	Repeated severe events over 30-year periods: CR; clustering of severe events within five-year windows: VU	hard coral cover	33.8% ± 14.1SD (n=37)	6.3% ± 2.9 SD (n=4)
				branching coral ratio	0.28 ± 0.32 SD (n=14)	0.07 ± 0.07 SD (n=4)
				algae-coral ratio	0.00 ± (n=2)	0.08 ± 0.04

Proportion of assessed reef sites falling below the 5% hard coral cover collapse	Distribution (Criterion B)		Observed thermal stress, 1985-2025 (Subcriterion C1)	Biotic Indicator Values (Criterion D)		
	EOO (km ²)	AOO		Indicator	Baseline	Current
						SD (n=4)

CR = Critically Endangered ; LC = Least Concern

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the **Arabian (Persian) Gulf – Inner** was assessed as **Critically Endangered (CR)**. This classification was supported by severe historical and projected thermal stress under subcriteria C1 and C2, as well as substantial biotic degradation under Criterion D. Half of the assessed reef sites had hard coral cover at or below the 5% collapse threshold, resulting in an Endangered classification under Criterion A. Its restricted geographic distribution was assessed as Vulnerable under Criterion B.

Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	EN	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	VU	VU	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1975)	Future or any 50y period	Historical (1750)
	CR	CR	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1975)	Future or Any 50y period	Historical (1750)
	CR	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; DD = Data Deficient; LC = Least Concern; NE = Not Evaluated.

Key findings and recommendations

- The ecoregion was classified as **Critically Endangered overall**, reflecting severe historical and projected thermal stress under subcriteria C1 and C2 and substantial biotic degradation under Criterion D.
- Half of the assessed reef sites had hard coral cover at or below the 5% collapse threshold, resulting in an Endangered classification under subcriterion A1.
- Hard coral cover and the proportion of branching corals have declined substantially from historical baselines.

- Its restricted geographic distribution resulted in a Vulnerable classification under Criterion B.
- Offshore framework-building reefs and marginal coastal systems remain exposed to multiple climate-related and local pressures.

Priority actions

- Protect remaining offshore framework-building reefs and sites that retain relatively high coral cover or structural complexity.
- Maintain long-term monitoring of coral cover, branching corals, algae, reef-fish communities and recovery following thermal-stress events.
- Expand long-term monitoring across the Inner Gulf to improve spatial coverage and strengthen future reassessments.
- Reduce pressures from desalination and industrial discharges, pollution, intensive fishing, abandoned fishing gear and recreational anchoring.
- Improve regional coordination to monitor changes in freshwater and sediment inputs from the Shatt al-Arab and their effects on reef condition.
- Assess where active management or restoration could support natural recovery after underlying pressures have been reduced.

Arabian (Persian) Gulf – Southeast (CR)

Spatial distribution

The Arabian (Persian) Gulf – Southeast ecoregion extends across the shallow southern Gulf, including the coastal and offshore waters of Bahrain, Qatar, Saudi Arabia and the United Arab Emirates, and contains an estimated 489.75 km² of coral habitat (Figure 1). It forms a subdivision of the original MEOW Arabian (Persian) Gulf ecoregion and was delineated to reflect its shallow bathymetry, distinct circulation and extreme seasonal variation in temperature and salinity.

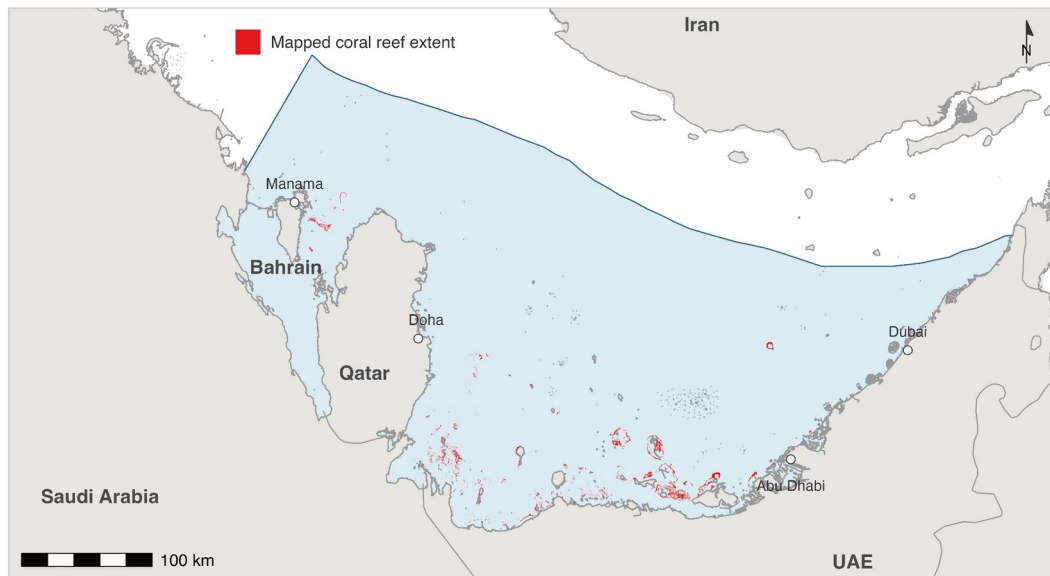


Figure 1. Distribution of the mapped coral reef habitat (red) in the Arabian (Persian) Gulf – Southeast ecoregion (blue).

Ecosystem description

Coral reefs of the Arabian (Persian) Gulf – Southeast are predominantly marginal systems, with localised framework-building reefs occurring offshore. Coral communities are dominated by stress-tolerant massive corals, including *Porites*, *Platygyra* and *Dipsastraea*. Remnant populations of branching *Acropora* persist on some offshore reefs, although their distribution and abundance have declined following repeated disturbances (Figure 2).

The ecoregion is characterised by extreme summer temperatures, with sea surface temperatures exceeding 36°C in some areas, together with hypersalinity driven by high evaporation and limited freshwater input. Seasonal Shamal winds influence water circulation, wave exposure and sediment resuspension, contributing to spatial variation in turbidity and reef conditions.



Figure 2. Coral communities at Sir Bu Nair Protected Area, Arabian (Persian) Gulf – Southeast, United Arab Emirates. Left: branching *Acropora* assemblages in 2019 (photo: Daniel Mateos-Molina). Right: massive corals and remnant *Acropora* in 2024 (photo: Rebekka Pentti).

The main pressures include recurrent mass-bleaching events and extensive coastal modification. Land reclamation and dredging have directly removed or altered reef habitat and increased sediment resuspension and turbidity across adjacent areas. Thermal and hypersaline brine discharges from coastal infrastructure create additional localised stress for coral communities already living close to their environmental limits.

Key ecosystem characteristics and threats

Ecoregion	Key Biotic	Key Abiotic	Key Threats
Arabian (Persian) gulf – Southeast	Predominantly marginal reefs with localised offshore framework-building reefs; stress-tolerant massive corals (<i>Porites</i> , <i>Platygyra</i> and <i>Dipsastraea</i>); remnant <i>Acropora</i> on offshore reefs.	Summer SSTs exceeding 36°C; hypersalinity; high evaporation; Shamal winds.	Recurrent mass bleaching; extensive land reclamation and dredging, with associated sediment resuspension and elevated turbidity; thermal and brine discharge, fishing pressure and abandoned gear.

Key values

Proportion of assessed reef sites falling below the 5% hard coral cover collapse threshold	Distribution (Criterion B)		Observed thermal stress, 1985-2025 (Subcriterion C1)	Biotic Indicator Values (Criterion D)		
	EOO (km ²)	AOO		Indicator	Baseline	Current
68% of 56 sites	116,581	148 occupied 10x10km grid cells	Repeated severe events over 30-year periods: EN; clustering of severe events within five-year windows: LC	hard coral cover	42.9% ± 23.3 SD (n=19)	8.0% ± 5.6 SD (n=30)
				branching coral ratio	0.76 ± 0.27 SD (n=13)	0.03 ± 0.09 SD (n=30)
				algae-coral ratio	0.13 ± 0.25 SD (n=7)	0.77 ± 0.16 SD (n=30)

NE = Not Evaluated; DD = Data Deficient

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the **Arabian (Persian) Gulf – Southeast** was assessed as **Critically Endangered (CR)**. This classification was supported by projected thermal stress under subcriterion C2 and severe biotic degradation under Criterion D, particularly the decline in branching corals. Historical thermal stress was assessed as Endangered under

subcriterion C1, while 68% of assessed reef sites had hard coral cover at or below the 5% collapse threshold, resulting in an Endangered classification under Criterion A.

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	EN	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	LC	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1975)	Future or any 50y period	Historical (1750)
	EN	CR	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1975)	Future or Any 50y period	Historical (1750)
	CR	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; DD = Data Deficient; LC = Least Concern; NE = Not Evaluated.

Key findings and recommendations

- The ecoregion was classified as **Critically Endangered overall**, reflecting the high risk associated with projected thermal stress under subcriterion C2 and severe biotic degradation under Criterion D.
- Based on observed thermal stress between 1985 and 2025, the ecoregion was classified as Endangered under subcriterion C1.
- Sixty-eight per cent of assessed reef sites had hard coral cover at or below the 5% collapse threshold, resulting in an Endangered classification under subcriterion A1.
- Hard coral cover and the proportion of branching corals have declined substantially, while the algae–coral ratio has increased.
- Its comparatively broad geographic distribution resulted in a Least Concern classification under Criterion B.

Priority actions

- Protect remaining offshore framework-building reefs, remnant *Acropora* communities and reefs that show resistance to or recovery from thermal stress.
- Maintain coordinated long-term monitoring of coral cover, branching corals, algae, reef-fish communities, bleaching and recovery.
- Reduce fishing pressure and physical damage from active and abandoned fishing gear around reefs.

- Reduce habitat loss and sedimentation associated with coastal development, land reclamation and dredging.
- Strengthen controls on thermal and brine discharges from coastal infrastructure.
- Prioritise recovery measures at severely degraded reefs while protecting sites that retain relatively high coral cover and ecological function.