REGIONAL REPORT V.0

Red List of Ecosystems assessment of South Asian coral reefs

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KEYWORDS

Red List of Ecosystems; coral reefs; ecosystem collapse; risk assessment; South Asia

ABSTRACT

South Asian coral reefs extend from approximately 10.80°S to 25.06°N across India, Bangladesh, Sri Lanka, the Maldives and the Chagos Archipelago. They cover an estimated 8,282.6 km^2, representing approximately 4% of global coral-reef extent, and encompass 13 ecoregions delineated using the Marine Ecoregions of the World framework and regional expert input. The region supports diverse reef-building corals, reef fishes and associated benthic communities across oceanic atolls, fringing, barrier, patch and platform reefs. Environmental settings range from clear, oligotrophic oceanic waters to highly turbid continental-shelf systems influenced by monsoon circulation, freshwater discharge, sedimentation, strong currents and seasonal upwelling. These ecosystems face interacting pressures from marine heatwaves and mass bleaching, overfishing and destructive fishing, coastal development, dredging, sedimentation, pollution, tourism, anchoring and reef-resource extraction.

The IUCN Red List of Ecosystems assessment applied Criteria A–D using coral-reef extent data, in-situ benthic and fish monitoring,

satellite-derived Degree Heating Weeks and records extending to 2026 where available. No ecoregions were assessed as Least Concern across all criteria, highlighting the widespread and escalating pressures facing reefs in the region. In summary, 54% (n=7) were Vulnerable, 31% (n=4) were Endangered and 15%(n=2) were assessed as Critically Endangered. Risk was driven most consistently by restricted geographic distribution under Criterion B; observed severe thermal stress under Criterion C1 and degradation of hard-coral cover and fish indicators under Criterion D increased risk in several ecoregions. Criterion A identified one Vulnerable ecoregion, while five ecoregions were Data Deficient under Criterion D. Projected thermal exposure for 2026–2075 indicated substantially greater risk once projected heat stress is included, although Criterion C2 was reported separately. The findings demonstrate an urgent need to reduce manageable local pressures, protect geographically restricted and recovery-capable reefs, strengthen spatial and long-term benthic and fish monitoring, validate reef-extent data, and integrate climate adaptation and coral-reef recovery into coordinated national and regional marine policy.

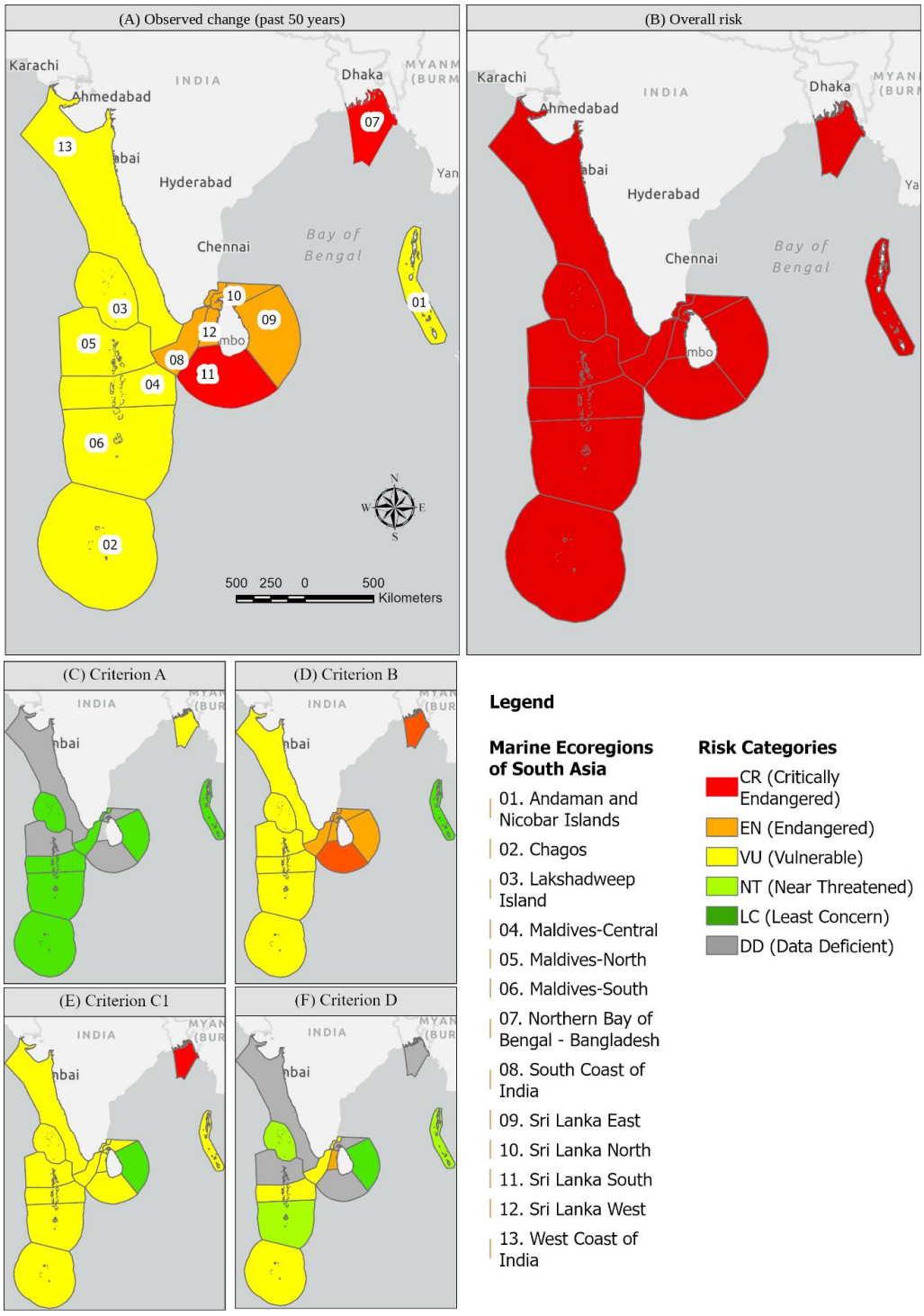


Figure 1. Distribution of the 13 coral reef ecoregions in South Asia. Panel A: Observed change, risk of collapse based on the past 50 years of observed change (criteria A, B, C1 and D). Panel B: Overall Red List of Ecosystems risk status, including projected heat stress over the next 50 years (criterion C2, IPCC SSP2-4.5). Panels C–F: risk status under criterion A (reduction in geographic distribution), criterion B (restricted geographic distribution), criterion C1 (environmental degradation, observed) and criterion D (disruption of biotic processes and interactions).

1. Study Area

This Red List of Ecosystems (RLE) assessment evaluates the risk of collapse for coral reefs across South Asia using the most recent data available for the assessment, including records through 2025 where available. South Asia coral reefs (IUCN Global Ecosystem Typology M1.3 - photic coral reefs) extend from approximately 10.80°S to 25.06°N across India, Bangladesh, Sri Lanka, Maldives, and Chagos. Overall, the region contains an estimated 10,949 km^2 of coral reefs, representing 4.22% of the global coral reef extent (Souter et al., 2021). However, after consultation with regional experts and validation with filed observations, reef extent included in this study are 8,282.6 km^2.

Coral reefs of South Asia were grouped into 13 ecoregions, drawing on the Marine Ecoregions of the World (MEOW) framework (Souter et al., 2021) and expert input from the first regional workshop for the South Asia Coral Reef RLE Assessment. These ecoregions capture broad regional-scale ecological variation in hard coral and reef fish biodiversity, reef structural complexity, hydrodynamic and monsoonal variability, freshwater and sediment inputs, productivity gradients, and exposure to mass bleaching, overfishing, coastal development, and land-based pollution. They are equivalent to level 4 of the IUCN Global Ecosystem Typology (regional sub-groups)(Keith et al., 2020). Coral reefs in each ecoregion were independently assessed using the IUCN Red List of Ecosystems criteria (details on data collection and monitoring are provided in Annex 1).

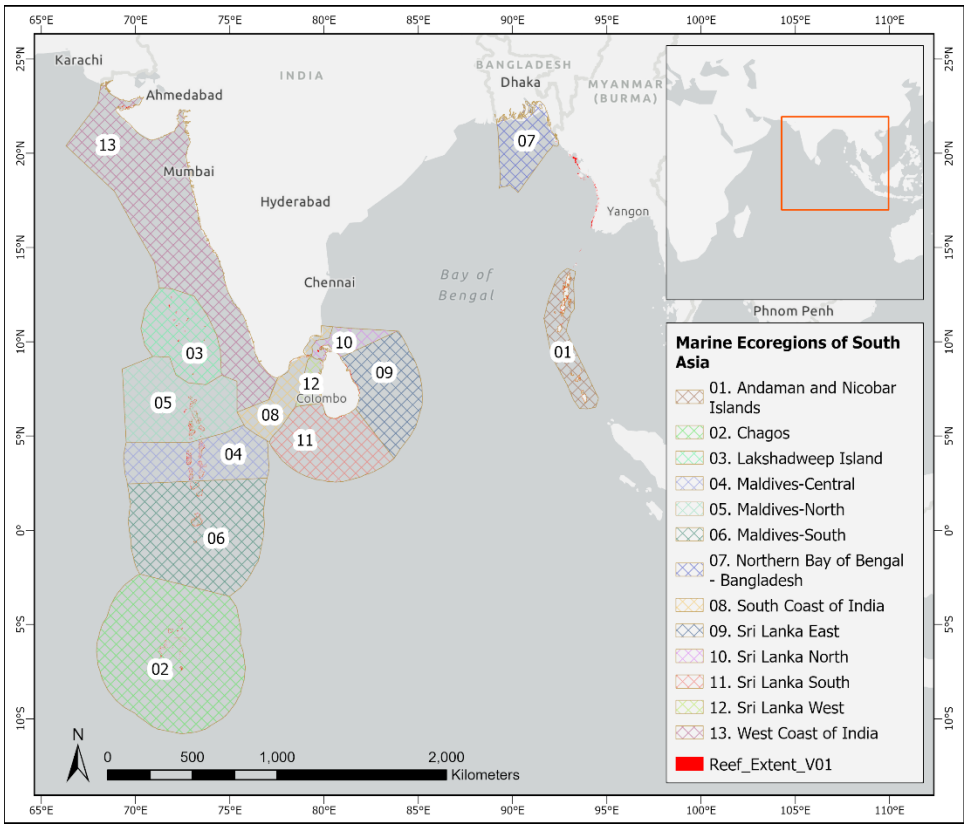


Figure 2. Coral reefs of South Asia, grouped within 13 coral reef ecoregions to be evaluated under the IUCN Red List of Ecosystems criteria and corresponding to Level 4 of the IUCN Global Ecosystem Typology.

2. Ecosystem Description

The coral reef ecosystems of South Asia occur across the Maldives, Sri Lanka, India (Lakshadweep, Gulf of Mannar, Andaman and Nicobar Islands), the Chagos Archipelago, and Bangladesh (limited reef formations). These reefs represent a transition zone between the high-diversity Coral Triangle to the east and the Arabian Sea systems to the west. They encompass fringing reefs, patch reefs, barrier-like formations, atoll systems (notably the Maldives and along the Chagos-Laccadive Ridge), and reef-associated lagoon systems.

A large proportion of South Asia's reef area is concentrated along the Lakshadweep-Maldives-Chagos ridge system, which accounts for roughly three-quarters of total regional reef area and creates a strong contrast between oceanic atoll reefs and mainland-associated reef systems (Souter et al., 2021). Other important reef systems occur in the Gulf of Mannar and around parts of Sri Lanka, while reef development is generally more limited along high-sediment, high-runoff mainland coasts, notably in eastern and northern sectors of the Bay of Bengal.

The region includes two main functional reef settings. Type A reefs are true, accreting reef frameworks, especially the oceanic atolls, fringing and barrier-like systems of the Maldives, Lakshadweep, and Chagos Archipelago, where carbonate production has built extensive reef flats, slopes, lagoons, and reef islands on the Laccadive-Chagos Ridge. Type B reefs are fringing, patch, rocky, and marginal reef communities on continental shelves and island coasts, including the Gulf of Mannar, Palk Bay, Sri Lanka, Andaman and Nicobar Islands, Gulf of Kachchh, and Saint Martin's Island in Bangladesh. Both settings share reef-building corals, reef fishes, carbonate production, herbivory, larval connectivity, and coral-algal competition as defining processes, but they differ in geomorphology, exposure to oceanic water, turbidity, sedimentation, freshwater influence, and the degree to which reef growth forms large accreting structures. This geological history helps explain why South Asia contains both extensive atoll systems and smaller mainland-associated reefs that function as coral reef ecosystems under more marginal environmental conditions.

2.1. Key Biotic Components

South Asia's photic coral reefs are biogenic carbonate structures formed primarily by hermatypic scleractinian corals and other calcifying organisms. These organisms create the three-dimensional habitat that supports reef fishes, benthic invertebrates, algae, seagrass-associated communities, and linked mangrove and lagoon systems (Keith et al., 2020; Souter et al., 2021). Across the region, dominant reef-building genera include *Acropora, Porites, Montipora, Pocillopora, DipsastreaFavites* and related *Merulinids, Goniastrea, Pavona, and Platygyra*, with composition varying among atolls, fringing reefs, rocky reefs, and high-turbidity mainland settings.

The reef matrix supports crustose coralline algae that provide settlement cues for coral larvae, fleshy and turf algae that compete with corals for space, sponges and soft corals, gorgonians, molluscs, echinoderms, and other sessile invertebrates (Abdul Wahab et al., 2023; Das et al., 2023; Ellepola et al., 2021). Reef fish assemblages are diverse and functionally structured, including herbivores such as parrotfishes and surgeon-fishes, planktivores, invertivores, and predators such as groupers and reef-associated sharks. These groups help maintain coral reef function through grazing, predation, bioerosion, nutrient transfer, and trophic regulation.

Distinctive biotic attributes are documented in several ecoregions. Sri Lankan reefs support at least 183 species of stony corals across 68 genera, with important reef-building families including *Acroporidae, Poritidae, Pocilloporidae*, and historically recognised faviid groups (Arunprakash et

al., 2025; Gunatilleke et al., 2017; Rajasuriya et al., 1995). Indian reef systems include extensive associated biodiversity, including algae, seagrasses, sponges, crustaceans, echinoderms, and reef fishes, with Lakshadweep supporting about 133 coral species in 44 genera and high fish diversity (Das et al., 2023; Gopi et al., 2021; Kar et al., 2022; Saroj et al., 2016). The Andaman-Nicobar region has very high A*croporid* diversity, while the Gulf of Kachchh and Palk Bay support lower-diversity but distinctive coral assemblages adapted to turbid and environmentally variable conditions (Kumar et al., 2014; Marimuthu et al., 2016; Saroj et al., 2016). Diversity in the Gulf of Mannar also has around 132 coral species (Edward et al., 2023).

In the Maldives, commonly observed genera include major Indo-Pacific reef builders such as *Acropora, Montipora, Porites, Pocillopora, Pavona, Cyphastrea*, and *Favites and Dipsastrea*, with lagoonal reefs often dominated by tabular and branching *Acropora* and ocean-facing reefs by massive *Poritidae* and branching *Pocilloporidae* (Donati et al., 2025; Dryden & Basheer, 2021; Rossi et al., 2017). In the Chagos Archipelago, coral diversity is high – approximately 300 reef-building coral species have been listed, whilstlong-term ecological accounts emphasise unusually high fish abundance compared with many more heavily fished Indian Ocean reefs, reflecting the role of strong protection in maintaining trophic structure (Sheppard et al., 2002, 2020).

Endemism and local biogeographic distinctiveness are likely to be highest where isolation and environmental filtering are strongest, including oceanic atoll systems, the Chagos Archipelago, Lakshadweep, Andaman and Nicobar Islands, and marginal mainland reefs. However, endemism should be reviewed with national experts and researchers because many coral and fish records remain uneven across ecoregions.

2.2. Key Abiotic Components

South Asian coral reefs occur mainly in warm, shallow photic waters where light availability, temperature, carbonate chemistry, salinity, turbidity, wave exposure, and sedimentation regulate reef growth and community composition. Most reef development occurs at depths shallower than approximately 30 m, although coral communities may extend deeper where water clarity permits. Accordingly, references to depths approaching 60 m should be interpreted as indicating an upper photic limit rather than the principal zone of reef-building activity (Keith et al., 2020; Montalbetti et al., 2022; Montefalcone et al., 2020).

The region covers strong environmental gradients associated with the Indian Ocean monsoon, continental runoff, and oceanic isolation. Oceanic atolls such as the Maldives, Lakshadweep, and Chagos generally experience clean, saline, and oligotrophic waters. Their offshore setting and

lack of major rivers limit terrestrial sediment and nutrient inputs, contributing to high water clarity (Sheehan et al., 2019). Lagon and outer-reef environments differ in water exchange, nutrient availability, and exposure to oceanic conditions (Sheehan et al., 2019). In contrast, mainland and island-shelf reefs in India, Sri Lanka, Bangladesh, and parts of the Bay of Bengal are more strongly influenced by river discharge, suspended sediments, monsoon-driven turbidity, nutrient inputs, and seasonal ocean circulation (Pillap, 1983; Rajasuriya et al., 1995; Souter et al., 2021; Thilakarathne et al., 2023).

Temperature conditions are similarly shaped by seasonal monsoon circulation, wind reversal, mixed-layer depth, and local upwelling or water exchange. Although most reef-building corals in the region occur in warm tropical waters, thermal exposure varies among habitats. Shallow lagoon reefs may experience greater daily and seasonal temperature fluctuations, whereas ocean-facing reefs may benefit from deeper and cooler water, stronger wave energy, and more effective flushing (Donati et al., 2025; Kench & Brander, 2006; Montefalcone et al., 2020).

These environmental contrasts are particularly evident in the Maldives, where atoll geomorphology, wave exposure, hydrodynamics, and water depth distinguish ocean-facing reefs from lagoon reefs. Outer-atoll reefs are exposed to stronger wave action and mixing and are generally less affected by land-derived nutrient inputs (Painter et al., 2023).. Lagoon reefs, by comparison, are typically shallower and less energetic, with greater potential for nutrient accumulation and thermal variability (Donati et al., 2025; Rovere et al., 2018). The close relationship between reefs and reef islands also creates important linkages between marine and terrestrial processes. Reef islands can store freshwater lenses above denser seawater, making shoreline change, erosion, accretion, and sea-level rise important processes influencing reef-island ecosystems (Carruthers et al., 2023).

In Sri Lanka, the monsoonal climate strongly influences turbidity and freshwater inputs. Extensive reef development is therefore limited in wetter and more sedimented coastal sectors, while better-developed reefs occur where water clarity is greater (Rajasuriya et al., 1995; Thilakarathne et al., 2023). In Lakshadweep, atoll geomorphology supports extensive lagoon systems and strong reef–lagoon coupling, with benthic production, seagrass, macroalgal, and other carbonate habitats contributing to the broader functioning of the reef-island system. Particularly, environmental contrast linked to the south west monsoon are also important where windward and leeward locations represent clear ecological regimes, with consequences for distribution of coral communities and recovery patterns (Arthur et al., 2006; Yadav et al., 2018).

2.3. Key Processes and Interactions

South Asia's coral reef ecosystems are maintained through the interaction of carbonate production, coral reproduction and recruitment, herbivory, trophic regulation, bioerosion, hydrodynamics, water quality, monsoonal shifts and disturbance–recovery processes. Reef-building corals and other calcifying organisms create the carbonate framework and structural complexity of the reef, while coral spawning, larval dispersal, and settlement help replenish populations following disturbance. In the Maldives, multi-species coral spawning has been observed during seasonal periods associated with monsoonal transitions, while settlement can be influenced by chemical and physical cues provided by crustose coralline algae (Abdul Wahab et al., 2023; Errington et al., 2025). In Lakshadweep, studies have shown that post-recruitment survival of coral is mediated by structural stability of settlement substrate, which, in turn, is mediated by monsoonal exposure (Yadav et al., 2016).

Herbivory by fishes and invertebrates is particularly important because it reduces turf and fleshy algae, maintains open space for coral recruits, and supports recovery following coral mortality events (Carlson et al., 2017; Ledlie et al., 2007). Where herbivores decline because of fishing or habitat degradation, macroalgae may become more abundant, inhibit coral recruitment, and reinforce a shift toward degraded reef states (Ledlie et al., 2007; Mumby et al., 2007). Predators such as groupers and reef-associated sharks also contribute to trophic regulation, while reef fishes more broadly influence nutrient transfer, bioerosion, and the distribution of grazing pressure across the reef.

Interactions among benthic organisms are closely linked to water quality and disturbance history. Elevated nutrient concentrations, sedimentation, reduced water movement, and repeated coral mortality can favour turf algae, fleshy macroalgae, sponges, and other competitive benthic organisms. These changes may reduce coral growth and limit the recruitment of new colonies. The relationship between environmental conditions and benthic community structure is especially important in river-influenced and densely populated coastal areas. Clearer oceanic atolls, by contrast, may be more strongly influenced by thermal stress, hydrodynamics, and exchange between lagoon and outer-reef environments.

Microbial processes and nutrient cycling provide an additional link between biological communities and their physical environment. Coral hosts and their endosymbionts efficiently recycle nutrients in oligotrophic waters (Davy et al., 2012), but external nutrient inputs can become harmful when they stimulate microbial activity (Smith et al., 2006), promote algal growth

(Lapointe, 1997), or increase susceptibility to disease (Vega Thurber et al., 2014). These processes have been documented in Sri Lankan reefs and Lakshadweep atolls, where monsoon-driven circulation and local pollution influence patterns of nutrient and microplastic accumulation (Abeysinghe et al., 2024; Arunprakash et al., 2025; Fairoz et al., 2023; Praved et al., 2025).

The balance between carbonate production and bioerosion ultimately determines whether reefs continue to accrete, retain their topographic complexity, and provide coastal protection. Although some carbonate-budget studies have been conducted outside South Asia, the underlying processes are relevant to the region. Further assessment is needed to quantify how local carbonate production, parrotfish bioerosion, urchin grazing, storm damage, and coral recovery following bleaching interact across South Asian ecoregions.

2.4. Main Threats

South Asia's coral reefs are exposed to interacting climate-related, local-use, and land-based pressures. Although the relative importance of these threats varies among ecoregions, consistent regional patterns are evident. The most immediate widespread threat is climate-driven thermal stress and mass coral bleaching, while persistent local pressures include overfishing and destructive fishing, coastal development, sedimentation, pollution, tourism-related damage, anchoring, coral extraction and historical coral mining, disease, and outbreaks of native corallivores such as crown-of-thorns sea stars (Souter et al., 2021). Reefs already degraded by local human activities generally have a reduced capacity to recover from climate-related disturbances (Montefalcone et al., 2020).

Thermal stress and coral bleaching have contributed to major regional declines in live hard-coral cover, particularly during the 1998 and 2016 El Niño-related events (Das et al., 2023; Montefalcone et al., 2020; Souter et al., 2000). Regional estimates suggest that approximately 70% of living hard coral was lost during the 1998 event. Coral cover declined to approximately 11.8% by 1999, recovered to about 39.4% by 2010, and declined again following the 2016 bleaching event to approximately 26.3% (Souter et al., 2021). Repeated bleaching can also create space for opportunistic algae and other benthic organisms, contributing to longer-term shifts in community composition, including in Lakshadweep and Gulf of Manner (Arthur, 2000; Raj et al., 2021; Das et al., 2023).

Other climate-related changes may further increase the vulnerability of South Asian reefs. Ocean acidification reduces carbonate-ion availability and aragonite saturation, potentially slowing

coral calcification and reef accretion. Sea-level rise is particularly concerning threat for low-lying reef-island systems such as the Maldives, Gulf of Manner and Lakshadweep, where human settlements and infrastructure depend partly on reef-mediated coastal protection (Hilmi et al., 2023; Souter et al., 2021). These climate pressures are likely to have the greatest consequences where they coincide with local degradation and reduced recovery capacity.

Fishing pressure is another major threat across many ecoregions. The removal of herbivores and predators can alter trophic structure and weaken ecological processes that support coral recovery. Fishing gear can also damage fragile corals through direct contact, while destructive fishing, reef-resource extraction, and anchoring by fishing and tourism vessels can cause physical breakage, particularly on shallow fringing reefs, reef flats, and heavily visited sites. The significance of these pressures should therefore be assessed alongside reef protection status, enforcement capacity, and the dependence of coastal communities on reef fisheries.

Land-based pressures are generally strongest near densely populated coasts and river-influenced waters. Runoff, sewage, agricultural inputs, dredging, reclamation, port development, coastal construction, and sedimentation can degrade water quality, suppress coral growth and recruitment, and increase turbidity. These impacts are particularly relevant to parts of Sri Lanka, mainland India, Bangladesh, and other nearshore reef systems (Rajasuriya et al., 1995; Souter et al., 2021). In the Maldives, historical coral mining was a major threat, especially around North Malé. Although this practice has been banned, waste disposal, pollution, overfishing, dredging and reclamation projects and unsustainable tourism remain important pressures (Brown & Dunne, 1988; Hilmi et al., 2023; Jaleel, 2013).

Marine debris, microplastics, and chemical contaminants are also important current and emerging stressors. Reef-building corals may act as long-term sinks for microplastics by incorporating particles into their skeletons. Field studies from southern and western Sri Lanka have documented microplastics associated with reef environments, including blue particles that may originate from packaging and fishing materials (Abeysinghe et al., 2024; Hansani et al., 2023; Reichert et al., 2022). Heavy metals associated with shipping, untreated sewage, fishing, and tourism have also been identified as potential ecological risks in Lakshadweep reef sediments (Antony et al., 2022).

Biological pressures include coral disease and outbreaks or elevated densities of native corallivores such as crown-of-thorns sea stars. These represent different mechanisms of impact: disease directly affects coral tissue health, whereas crown-of-thorns sea stars cause coral

mortality through predation. In Lakshadweep, crown-of-thorns outbreaks are not currently considered a major threat, although outbreaks were reported historically during the 1990s. Information on coral diseases across Indian ecoregions remains limited (Das et al., 2023; Sharma & Ravindran, 2020). In Sri Lanka, periodic crown-of-thorns infestations appear to be more pronounced along the northwest and east coasts than in some other areas (Ellepola et al., 2021).

For this assessment, threats were recorded in consultation with regional experts using the IUCN Threat Classification Scheme (Table.1).

Table 1. Occurrence of major threats impacting coral reefs in each ecoregion categorised based on the IUCN Threat Classification Scheme

Threat type	Subcategory	Ecoregions												
		Adama nand	Chagos	Laksha dweep	Maldiv es	Maldiv es	Maldiv es	Northe rn Bay	South Coast	Sri Lanka	Sri Lanka	Sri Lanka	Sri Lanka	West Coast
		1	2	3	4	5	6	7	8	9	10	11	12	13
1. Residential & commercial development	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 & Other Problematic Species, Genes & Diseases	8.1 Invasive non-native species	✓	✓	✓					✓					✓
9. Pollution	9.1 Domestic & urban wastewater	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	9.2 Industrial & military effluents (Oil spills)		✓	✓				✓	✓	✓	✓	✓	✓	✓
	9.3 Agricultural & forestry effluents	✓		✓				✓	✓	✓	✓	✓	✓	-
11. Climate change & severe weather	11.3 Temperature extremes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	11.4 Storms & flooding	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

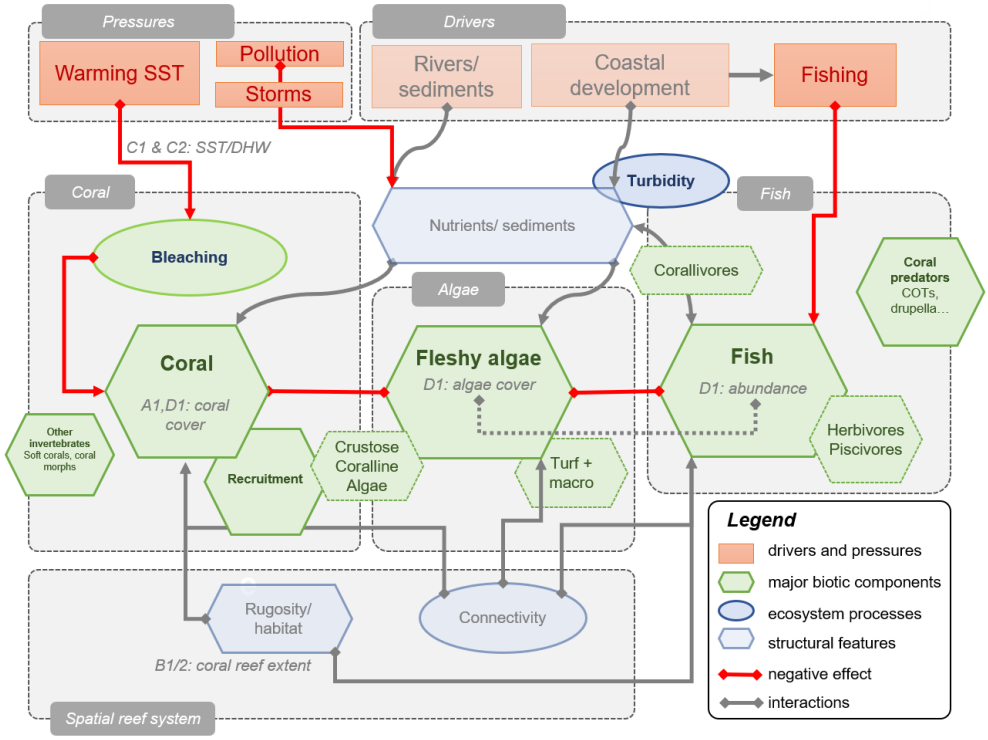


Figure 3. Conceptual model of the South Asia coral reef ecosystems. The model illustrates key biotic and abiotic components, as well as external drivers, threats, and the processes and interactions between them.

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 biodiversity and features decline to levels where the ecosystem transforms into a different type or is completely lost. This state can result from pathways that reduce the capacity of an ecosystem to sustain its characteristic biota, such as disease, overharvesting, land reclamation, coastal development, or a persistent change in environmental conditions. Collapse can occur locally, for example on a single reef. For an ecosystem type to be classified as Collapsed, it must have fully declined or degraded across its entire distribution, although recovery may still be possible under conducive conditions.

For coral reefs, collapse is signalled by the near or complete loss of hard corals to levels where defining processes such as carbonate accretion are absent or negligible. A collapsed reef would have extremely low coral richness and diversity, with communities dominated by a few weedy or stress-tolerant species. Collapsed coral reefs are often characterised by a phase shift from coral dominance to high abundances of turf and fleshy algae, rubble, sponges, or other filter-feeding invertebrates. This state is also associated with low abundance and diversity of other key biodiversity, including altered fish communities. In some cases, collapse corresponds to

simplified topographic structure or occurs where the geomorphological structure of coral reefs permanently disappears through land reclamation or coastal development.

Under the Red List of Ecosystems framework, collapse can be defined as the point at which key biotic or abiotic indicators reach thresholds where the ecosystem's defining features are, or would be, lost.

For this assessment, coral reef ecosystem collapse is defined by any of the following:

- complete loss of coral reef area;
- hard coral cover falling below 5%; or
- sea surface temperatures exceeding critical thresholds, resulting in frequent severe heatwaves and coral bleaching at an average return time between events of 5 years.

In addition, the following biotic indicators reflect severe functional degradation but not complete ecosystem collapse and can be used to elevate risk levels:

- an algal-to-coral cover ratio exceeding 5:1;
- severe depletion of key fish groups, such as herbivores and piscivores, to levels well below historical baselines.

Table 3. Key abiotic and biotic features and characteristics of the coral reef's ecoregions in South Asia**,** highlighting unique aspects of each ecosystem.

ID	Ecoregion	Key biotic components	Key abiotic components	Key threats
1	Andaman and Nicobar Islands	High Acropora diversity; diverse coral, reef-fish and benthic-invertebrate assemblages	Oceanic island and shelf reefs influenced by monsoon circulation	Fishing pressure, thermal bleaching, and coastal development
2	Chagos	Approximately 300 reef-building coral species; abundant reef fishes and well-developed trophic structure	Remote, clear-water oceanic reefs with limited land-based influence	Thermal bleaching, ocean warming and acidification
3	Lakshadweep Island	Approximately 133 coral species in 44 genera; high reef-fish diversity; associated seagrass, macroalgal and benthic communities	Clear, saline and oligotrophic atoll waters; extensive lagoons and strong reef–lagoon coupling	Bleaching, fishing, tourism, pollution and sea-level rise
4	Maldives-Central	Major Indo-Pacific reef-building corals; diverse reef fishes and benthic communities	Atoll reefs with contrasting lagoon and ocean-facing environments	Bleaching, tourism, fishing, pollution and coastal modification
5	Maldives-North	Major Indo-Pacific reef-building corals; diverse reef fishes and benthic communities	Clear, oligotrophic atoll waters influenced by currents and reef–lagoon exchange	Bleaching, tourism development, fishing and pollution
6	Maldives-South	Major Indo-Pacific reef-building corals; diverse reef fishes and benthic communities	Oceanic atolls with clear water, wave-exposed outer reefs and sheltered lagoons	Bleaching, ocean warming, fishing and tourism-related pressures
7	Northern Bay of Bengal – Bangladesh	Hard and soft corals occurring on rocky habitats; coral and associated benthic communities requiring further ecoregion-level documentation	Shallow, highly turbid waters strongly influenced by monsoon rainfall, river discharge and sediment inputs	Sedimentation, pollution, tourism-related coastal development and climate stress
8	South Coast of India	Coral assemblages adapted to turbid and environmentally variable conditions; associated with reef fishes, seagrasses and invertebrates	Shallow nearshore reefs influenced by monsoons, sedimentation and seasonal circulation	Thermal belaching.
9	Sri Lanka East	Reef-building corals, reef fish and benthic invertebrates	Monsoon-influenced coastal reefs with seasonal changes	Bleaching, sedimentation, coastal development and

ID	Ecoregion	Key biotic components	Key abiotic components	Key threats
			in currents, turbidity and wave exposure	periodic crown-of-thorns infestations
10	Sri Lanka North	Reef-building corals, reef fish and benthic invertebrates	Shallow coastal reefs influenced by monsoon variability, turbidity and freshwater inputs	Fishing, pollution, sedimentation and habitat degradation
11	Sri Lanka South	Reef-building corals, reef fish and benthic invertebrates	Wave-exposed coastal reefs with generally clearer water in suitable sectors	Bleaching, tourism, pollution and coastal development
12	Sri Lanka West	Reef-building corals, reef fish and benthic invertebrates	Coastal reefs exposed to seasonal monsoon-driven turbidity, runoff and wave conditions	Bleaching, tourism, sedimentation, pollution and coastal development
13	West Coast of India	Distinctive coral assemblages adapted to turbid and environmentally variable conditions; reef fishes and benthic invertebrates	Shallow nearshore reefs influenced by monsoon circulation, river runoff and sedimentation	Coastal development, sedimentation, pollution and fishing

3. Criterion Assessment

The Coral reefs in 13 ecoregions within the South Asia were assessed using IUCN Red List of Ecosystems (RLE) Criteria A–D. The following section briefly describes the approach used for each criterion with the detailed methods presented in the Annex.

3.1. Criterion A: Reduction in Geographic Distribution

Decline in distribution of coral reefs over the past 50 years was assessed using hard coral cover data and was calculated as the proportion of reef sites currently with less than 5% hard coral cover, which is an 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%. Reefs with declines of 27–30% were classified as Near Threatened, and all others were considered Least Concern (Table.4).

3.2. Criterion B: Restricted Geographic Distribution

Criterion B assess 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. Both were derived using the Millennium Coral Reef Layer, and local data set validated by regional, national 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 (IUCN, 2024).

3.3. 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 (sub-criterion C1, 1975–2025) and projected changes over the next 50 years (sub-criterion C2, 2026–2075). For both periods, annual maximum Degree Heating Weeks (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 treated as the primary scenario. 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 2 was taken as the final risk status under Criterion C.

3.4. Criterion D: Disruption of Biotic Processes and Interactions

Criterion D assesses the disruption to three key biotic components over the past 50 years. This includes coral cover, algae-to-coral ratio, herbivore biomass, and piscivore biomass derived from in-situ monitoring data. For each reef site, the decline in each indicator is measured relative to both the state of the reef 50 years ago and a hypothetical collapse threshold, representing the point at which that biotic component is no longer functional. The proportion of sites experiencing varying degrees of decline is then evaluated, and a risk matrix is used to determine the risk status for each indicator. Finally, a heuristic, stepwise approach across all indicators is applied to derive the overall risk status under Criterion D for each ecoregion.

Table 4. Methodology, parameters and collapsed thresholds used to assess Coral Reefs ecosystems in South

Asia under the Red List of Ecosystem criteria.

Criterion	Sub-criterion	Indicator(s)	Data Sources	Collapse Threshold(s)	Criterion Assessed? (Yes/No)	Notes
A. Reduction in geographic distribution	A1 – Past 50 years	Proportion of monitored sites classified as locally collapsed using recent hard-coral cover	Compiled South Asia benthic monitoring dataset; site-level percentage hard-coral cover	Local collapse: hard-coral cover ≤5%. Ecoregion category: CR ≥80%; EN 50–<80%; VU 30–<50%; NT 25–<30%; LC <25%	Yes	Operational proxy based on recent observations from 2020 onward. Thresholds from 1–10% were tested; the final assessment used 10%.
B. Restricted geographic distribution	B1 – Extent of Occurrence (EOO)	Area of the minimum convex polygon enclosing mapped reef occurrences within each ecoregion	Regional coral-reef extent GIS layer and ecoregion polygons	CR: EOO ≤2,000 km^2; EN: ≤20,000 km^2; VU: ≤50,000 km^2; EOO >50,000 km^2 assigned NT/LC and presented as LC in the final report	Yes	EOO calculated separately for each ecoregion using a minimum convex polygon. Threat-defined locations were not independently parameterized in the code.
	B2 – Area of Occupancy (AOO)	Number of occupied 10 × 10 km grid cells; a cell is occupied when it contains >1 km^2 of reef	Regional coral-reef extent GIS layer and ecoregion polygons	CR: AOO ≤2 cells; EN: ≤20; VU: ≤50; NT: 50–55; LC: >55 cells	Yes	AOO represents occupied 10-km grid cells, not total reef area in km^2.
C. Environmental degradation	C1 – Observed environmental degradation	Annual maximum Degree Heating Weeks (DHW); shortest severe-event return interval across rolling 30-year windows; maximum severe-event count across rolling 5-year windows	NOAA Coral Reef Watch 5-km observed DHW data, 1985–2024	Primary DHW ≥4 thresholds: chronic high-frequency condition ≤5-year return interval; chronic severe-collapse condition ≤3-year return interval; acute collapse ≥2 events in 5 years. DHW ≥12 sensitivity thresholds: chronic ≤5-year return interval and acute ≥3 events in 5 years	Yes	Acute baseline: maximum event frequency during 1985–1991. Initial chronic return interval: 10 years for DHW ≥8 and 15 years for DHW ≥12. The final C1 category is the worst result among the primary and primary-conservative DHW ≥8 components.
	C2 – Projected future environmental degradation	Projected severe-bleaching return intervals over rolling 30-year windows and severe-event clustering over rolling 5-year windows	Mellin et al. (2024) projected annual/seasonal maximum DHW under SSP2-4.5, SSP3-7.0 and SSP5-8.5	Chronic primary: DHW ≥8 after 2026 and collapse at ≤3-year return interval; ≤5 years tested as sensitivity. Acute primary: DHW ≥12 after 2026 and collapse at ≥3 events per 5 years; ≥2 events per 5 years tested as sensitivity	Yes	Future assessment period: 2026–2075. Chronic baseline: 1996–2025; acute baseline: 2016–2025. Alternative DHW thresholds were also assessed. C2 results were reported separately and were not used in the final Criterion C or overall category. .
D. Disruption of biotic	D1 – Hard-coral cover	Relative decline in site-level hard-coral cover from a	Compiled South Asia benthic-cover surveys and reviewed historical	Ecosystem collapse condition: hard-coral cover ≤5%	Yes	Baseline uncertainty was propagated through 1,000 truncated-normal

Criterion	Sub-criterion	Indicator(s)	Data Sources	Collapse Threshold(s)	Criterion Assessed? (Yes/No)	Notes
		historical or proxy baseline; spatial extent of decline	baseline datasets			simulations. Ecoregions without an adequate baseline were assigned DD.
	D1 – Algae–coral ratio	Current grouped-algae-to-hard-coral ratio relative to baseline; proportion of sites exceeding relative-severity thresholds	Compiled South Asia benthic-cover surveys; grouped algae, including turf algae, and hard-coral cover	Collapse ACR ≥0.833; warning threshold ACR ≥0.500	Yes	ACR categories were estimated across 1,000 baseline-uncertainty iterations. Missing or inadequate data resulted in DD. Macroalgae-only and observed-baseline calculations were retained as sensitivity analyses.
	D1 – Key fish consumers: parrotfish	Scaridae density or biomass relative to an ecoregion-specific reference baseline	South Asia underwater visual census fish records and reviewed fish reference baselines	South Coast of India: collapse threshold 139 in the recorded density metric. Chagos: 55.6 in the recorded biomass metric	Yes	Assessable fish results were available only for South Coast of India and Chagos; other ecoregions were DD. Categories were summarized as the modal result across 1,000 uncertainty iterations.
	D1 – Key fish consumers: groupers	Serranidae density or biomass relative to an ecoregion-specific reference baseline	South Asia underwater visual census fish records and reviewed fish reference baselines	South Coast of India: collapse threshold 307 in the recorded density metric. Chagos: 45.7 in the recorded biomass metric	Yes	Assessable fish results were available only for South Coast of India and Chagos; other ecoregions were DD. Categories were summarized as the modal result across 1,000 uncertainty iterations.

4. Risk Status

Coral reefs across all ecoregions of South Asia were at a high risk of collapse (Vulnerable, Endangered or Critically Endangered). All 13 of the 13 ecoregions were classified in threatened categories, with Critically Endangered risk levels in two ecoregions, Northern Bay of Bengal–Bangladesh and Sri Lanka South, driven by highly restricted geographic distribution (Criterion B1). No ecoregions were assessed as Least Concern across all criteria, highlighting the widespread and escalating pressures facing reefs in the region. In summary, 54% (n=7) were Vulnerable, 31% (n=4) were Endangered and 15%(n=2) were assessed as Critically Endangered.

Table 5. Summary of RLE assessment results for South Asia coral reef ecoregions. The overall Red List of Ecosystems status is the highest level of risk identified across all the assessed criteria.

Ecoregion	A1	B1	B2	C1	C2	D1	Observed change	Overall risk
Andaman and Nicobar Islands	LC	LC	LC	VU	CR	NT	VU	CR
Chagos	LC	VU	LC	VU	CR	VU	VU	CR
Lakshadweep Island	LC	NT	VU	VU	CR	NT	VU	CR
Maldives-Central	LC	VU	LC	VU	CR	VU	VU	CR
Maldives-North	DD	VU	LC	VU	CR	DD	VU	CR
Maldives-South	LC	VU	LC	VU	CR	NT	VU	CR
Northern Bay of Bengal - Bangladesh	VU	CR	EN	CR	CR	DD	CR	CR
South Coast of India	LC	EN	VU	VU	CR	VU	EN	CR
Sri Lanka East	LC	EN	VU	LC	CR	LC	EN	CR
Sri Lanka North	DD	EN	EN	VU	CR	DD	EN	CR
Sri Lanka South	DD	CR	EN	VU	CR	DD	CR	CR
Sri Lanka West	NT	EN	EN	VU	CR	EN	EN	CR
West Coast of India	DD	LC	VU	VU	CR	DD	VU	CR

11.2. Criterion A: Reduction in Geographic Distribution

Among the eight ecoregions assessed under Criterion A, Northern Bay of Bengal - Bangladesh was the only ecoregion classified within a threatened category, assessed as Vulnerable (VU), with 45% of monitored reef sites having recent hard-coral cover at or below the 5% local-collapse threshold (Table 6). The remaining seven assessed ecoregions were classified as Least Concern (LC) and Near Threatened (NT), with the proportion of sites at or below the threshold ranging from 0% to 25%. Four of the 13 ecoregions considered were classified as Data Deficient (DD) due to insufficient data for assessment.

Table 6. Risk status of South Asian coral reef ecoregions under Criterion A, determined from the proportion of monitored reef sites with recent hard-coral cover at or below the 5% local-collapse threshold.

Coral reef ecoregion	Proportion of reef sites below or equal to the critical hard-coral-cover threshold	Risk status
Andaman and Nicobar Islands	0.07	LC
Chagos	0.00	LC
Lakshadweep Island	0.05	LC
Maldives-Central	0.18	LC
Maldives-North	-	DD
Maldives-South	0.00	LC
Northern Bay of Bengal - Bangladesh	0.45	VU
South Coast of India	0.03	LC
Sri Lanka East	0.00	LC
Sri Lanka North	-	DD
Sri Lanka South	-	DD
Sri Lanka West	0.25	NT
West Coast of India	-	DD

4.1. Criterion B: Restricted Geographic Distribution

Under Criterion B, 6 of the 13 ecoregions were assessed as Endangered or Critically Endangered. A further 6 ecoregions were Vulnerable, while only 1 ecoregion was assessed as Least Concern. The most geographically restricted reef ecosystems were Northern Bay of Bengal - Bangladesh, with an EOO of approximately 338 km^2 and an AOO of 6 occupied grid cells, and Sri Lanka South, with an EOO of approximately 1,898 km^2 and an AOO of 12 occupied grid cells. Both were classified as Critically Endangered because of their restricted EOO under B1. Their limited distributions increase their susceptibility to spatially concentrated pressures, including coral bleaching, sedimentation, pollution and coastal development.

Table 7. Risk status of South Asian coral reef ecoregions under Criterion B, determined from the distribution of coral reefs measured as Extent of Occurrence (EOO) and Area of Occupancy (AOO). The combined Criterion B status is the higher risk category obtained from B1 or B2.

Coral reef ecoregion	Extent of Occurrence, EOO (km^2)	Area of Occupancy, AOO (occupied 10-km grid cells)	Determining sub-criterion		Risk status
			B1	B2	
Andaman and Nicobar Islands	76,611	213	LC	LC	LC
Chagos	45,278	199	VU	LC	VU
Lakshadweep Island	51,259	44	NT	VU	VU
Maldives-Central	22,195	144	VU	LC	VU
Maldives-North	22,842	133	VU	LC	VU
Maldives-South	22,088	99	VU	LC	VU
Northern Bay of Bengal - Bangladesh	338	6	CR	EN	CR
South Coast of India	6,050	23	EN	VU	EN
Sri Lanka East	2,072	24	EN	VU	EN
Sri Lanka North	3,208	20	EN	EN	EN
Sri Lanka South	1,898	12	CR	EN	CR
Sri Lanka West	4,173	20	EN	EN	EN
West Coast of India	117,673	33	LC	VU	VU

4.2. Criterion C: Environmental Degradation

Based on observed extreme thermal-stress conditions measured using Degree Heating Weeks (DHW), one of the 13 ecoregions were classified as Critically Endangered under Criterion C1. Sri Lanka East was classified as Least Concern, while the remaining 11 ecoregions were classified as Vulnerable.

The C1 assessment evaluated changes in the frequency and temporal clustering of severe thermal-stress events between 1985 and 2024. Chronic degradation was assessed using the shortest return interval of DHW ≥4 events over rolling 30-year windows, while acute degradation was assessed using the maximum number of DHW ≥8 events occurring within rolling five-year windows.

Projected C2 results for 2026–2075 indicated substantially greater risk once projected heat stress is included. Under SSP2-4.5, SSP3-7.0 and the SSP5-8.5 sensitivity scenario, all ecoregions were projected as Critically Endangered.

Table 8. Risk status of South Asian coral reef ecoregions under Criterion C, determined from observed and projected changes in extreme thermal-stress events measured using Degree Heating Weeks.

Coral reef ecoregion	Risk status Criterion C1	Risk status Criterion C2	Overall
Andaman and Nicobar Islands	VU	CR	CR
Chagos	VU	CR	CR
Lakshadweep Island	VU	CR	CR
Maldives-Central	VU	CR	CR
Maldives-North	VU	CR	CR
Maldives-South	VU	CR	CR
Northern Bay of Bengal - Bangladesh	CR	CR	CR
South Coast of India	VU	CR	CR
Sri Lanka East	LC	CR	CR
Sri Lanka North	VU	CR	CR
Sri Lanka South	VU	CR	CR
Sri Lanka West	VU	CR	CR
West Coast of India	VU	CR	CR

11.3. Criterion D: Disruption of Biotic Processes and Interactions

Four of the eight ecoregions with sufficient data for an overall Criterion D assessment were classified within threatened categories (Table 9). Sri Lanka West showed the highest overall risk, classified as Endangered (EN), while Chagos, Maldives-Central and South Coast of India were classified as Vulnerable (VU). Three ecoregions, Andaman and Nicobar Islands, Lakshadweep Island and Maldives-South, were classified as Near Threatened (NT), while Sri Lanka East was classified as Least Concern (LC). The remaining five ecoregions, Maldives-North, Northern Bay of Bengal–Bangladesh, Sri Lanka North, Sri Lanka South and West Coast of India, were Data Deficient (DD) for the overall Criterion D assessment.

Risk also varied among the four biotic indicators. Hard-coral cover showed elevated risk across several ecoregions, ranging from Near Threatened in Andaman and Nicobar Islands, Chagos, Lakshadweep Island and Maldives-South to Vulnerable in Maldives-Central and South Coast of India, and Endangered in Sri Lanka West. The algae–coral ratio generally indicated lower levels of risk, with classifications ranging from Least Concern to Near Threatened among ecoregions with sufficient data. Fish indicators had more limited coverage: parrotfish and grouper were Data Deficient across most ecoregions, although available data indicated elevated risk for both parrotfishes and groupers in South Coast of India and, for groupers, in Chagos.

Table 9. Risk status of South Asian coral reef ecoregions under Criterion D, based on estimated changes in key biotic indicators: hard-coral cover, algae–coral ratio, parrotfish and grouper indicators. The overall Criterion D status reflects the final stepwise interpretation of biotic degradation for each ecoregion. Ranges in risk e.g. EN-CR, represents uncertainty in the outcomes, and where relevant the most likely category is presented (outside of the parentheses) in addition to the range.

Coral reef ecoregion	Hard corals	Algae –coral ratio	Parrotfish	Groupers	Overall Criterion D
Andaman and Nicobar Islands	NT	LC	DD	DD	NT
Chagos	NT	LC	LC	EN	VU
Lakshadweep Island	NT (LC-NT)	NT	DD	DD	NT
Maldives-Central	VU	NT	DD	DD	VU
Maldives-North	DD	DD	DD	DD	DD
Maldives-South	NT	NT	DD	DD	NT
Northern Bay of Bengal - Bangladesh	DD	DD	DD	DD	DD
South Coast of India	VU	NT	NT - VU	VU	VU
Sri Lanka East	LC	LC	DD	DD	LC
Sri Lanka North	DD	DD	DD	DD	DD
Sri Lanka South	DD	DD	DD	DD	DD
Sri Lanka West	EN	NT (NT-VU)	DD	DD	EN
West Coast of India	DD	DD	DD	DD	DD

5. Conclusion and recommendations

This assessment indicates that ecosystem-collapse risk is already widespread across South Asian coral reefs. All 13 assessed ecoregions were classified as threatened: two Critically Endangered, four Endangered and seven Vulnerable. Northern Bay of Bengal – Bangladesh and Sri Lanka South were Critically Endangered under Criterion B1 because their restricted distributions provide limited spatial buffering against major disturbances. Under Criterion C1, observed thermal stress produced six Endangered and one Vulnerable classification, while Criterion D yielded threatened classifications for four of the eight ecoregions with adequate biotic data; five remained Data Deficient. the projected clustering of severe-bleaching events suggests that recovery intervals may become progressively shorter by 2075. The convergence of restricted distribution, recurrent thermal exposure and deterioration of key biotic components indicates reduced recovery capacity. However, RLE categories represent relative collapse risk rather than deterministic forecasts and should remain distinguishable from subsequent conservation-priority decisions (Rodríguez et al., 2015).

The first priority is a technical consolidation of the assessment. Versioned ecosystem boundaries, input data, analytical scripts and uncertainty records should be archived, followed by independent review of ecosystem definitions, collapse thresholds and indicator selection. Sensitivity analyses should quantify whether classifications change under alternative historical baselines, collapse thresholds, observation periods, spatial resolutions and treatments of missing

data. For Criterion B, reef-extent maps should be validated against recent imagery and field observations, and the number of threat-defined locations and evidence of continuing decline should be documented explicitly. For Criteria C1 and C2, ecoregion-specific relationships among degree heating weeks (DHW), bleaching severity, coral mortality and recovery should be estimated by linking satellite-derived heat exposure with dated field observations. The conventional 4 and 8°C-week levels can provide provisional survey triggers, but should not be assumed to represent identical ecological responses across ecoregions because bleaching sensitivity varies among taxa and environmental settings (Liu et al., 2014; McClanahan et al., 2020).

Over the near future, the five Data Deficient ecoregions should be addressed through a stratified, repeated-measures design covering reef zone, depth, exposure and human-pressure gradients. Georeferenced photoquadrats or orthomosaics should measure hard-coral cover, algal functional groups, recruitment, disease and crown-of-thorns occurrence. Length-based fish surveys should estimate parrotfish and grouper biomass, while turbidity, sediment deposition and dissolved nutrients should be measured at land-influenced reefs. Sampling methods, taxonomic groupings, metadata and quality-control rules must be harmonized before fieldwork so that observations can be integrated without obscuring methodological differences (Wicquart et al., 2022). Annual pre-bleaching-season surveys should establish baselines; DHW ≥4°C-weeks should trigger rapid bleaching surveys, followed by mortality and recovery surveys at approximately three, six and twelve months.

Management should be assigned according to the mechanism producing risk. Restricted-range reefs require prevention of further spatial loss; sediment- and sewage-affected reefs require measurable catchment and wastewater controls; and reefs with depleted herbivore biomass require enforceable fishery interventions. Restoration should proceed only after the dominant local stressor is controlled and should use replicated intervention and reference sites, predefined ecological endpoints, and monitoring extending beyond short-term colony survival (Boström-Einarsson et al., 2020). Indicators should be updated annually, with formal RLE reassessment every five years or immediately after a region-wide mass-bleaching event.

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7. 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.

8. Disclaimer

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11. Annex

11.1. Boundary definitions

The South Asia coral reef assessment was divided into 13 spatially distinct Units of Assessment. Their boundaries were derived from the *Marine Ecoregions of the World* (MEOW) bioregionalisation (Spalding et al., 2007). MEOW distinguishes coastal and shelf areas using patterns in species composition, oceanography, geomorphology and ecological connectivity. All assessment units fall within the Western Indo-Pacific realm and represent parts of the West and South Indian Shelf, Central Indian Ocean Islands and Bay of Bengal provinces.

Regional refinements were introduced where the original MEOW units were too broad to represent important differences in reef setting or environmental exposure. The decision were made with the judgement of the countries' respective coral reef ecosystem expert during the workshops and virtual technical meetings. The Maldives were divided into northern, central and southern units; Sri Lanka was divided into eastern, northern, southern and western units; and the continental and oceanic reefs of India were represented separately. The Northern Bay of Bengal – Bangladesh unit was also retained separately because its coral communities occur under exceptionally high freshwater, sediment and turbidity influence.

The marine ecoregion polygons were clipped to the regional coastline to remove terrestrial areas. The resulting boundaries were used to assign reef polygons, monitoring sites and environmental observations to their respective Units of Assessment.

Coral reef area refers only to mapped reef habitat contained within each boundary, not the total marine area of the ecoregion. Reef polygons were intersected with the updated ecoregion boundaries, dissolved by ecoregion and measured in the projected coordinate reference system WGS 84/UTM Zone 43N (EPSG:32643). The 13 units contain approximately 8,282.6 km^2 of mapped coral reef habitat. Eastern Coast of India and Northern Bay of Bengal–Myanmar were present in the source spatial layer but were not included in the final regional assessment outputs.

Table 10. Units of Assessment and boundary definitions used for the South Asia coral reef Red List of Ecosystems assessment.

Ecoregion	Country/ Territory	Coral reef area (km^2)	Boundary description	Justification
Andaman and Nicobar Islands	India	1,092.5	MEOW-derived marine polygon enclosing the Andaman and Nicobar Island chain and its associated fringing, platform and offshore reefs. It is separated from the continental margins of India, Bangladesh and Myanmar.	These are oceanic island reefs with clear-water conditions and strong connectivity with the eastern Indo-Pacific. Their coral diversity, exposure and reef geomorphology differ from the turbid continental reefs of the Bay of Bengal.
Chagos	Chagos Archipelago	1,188.2	MEOW-derived unit surrounding the Chagos Archipelago and its associated atolls, submerged banks, lagoons and outer-reef systems in the central Indian Ocean.	Chagos is a remote oceanic reef system with high water clarity, low terrestrial sediment input and strong regional connectivity. Its isolation and limited direct land-based pressures distinguish it from the populated reef systems farther north.
Lakshadweep Island	India	436.1	Marine polygon enclosing the Lakshadweep atolls and associated lagoon and outer-reef habitats, separated from the continental West Coast of India unit.	Lakshadweep consists principally of oceanic atoll and lagoon systems in oligotrophic Arabian Sea waters. These reefs differ from the more turbid, sediment-influenced patch reefs along mainland western India.
Maldives-Central	Maldives	1,990.4	Regional subdivision of the broader Maldives MEOW unit covering the central atoll chains and their lagoons, channels and outer reefs.	The large central atoll systems have strong inter-atoll connectivity and extensive lagoon, channel and outer-reef habitats. Their geomorphology and monsoon exposure differ from the northern and equatorial southern atolls.
Maldives-North	Maldives	1,271.8	Regional subdivision enclosing the northern Maldives atolls and their associated lagoon, channel and outer-reef habitats.	Northern atolls experience a distinct northern Indian Ocean monsoon and circulation setting. Differences in exposure, connectivity and atoll structure support their treatment separately from the central and southern Maldives.
Maldives-South	Maldives	837.8	Regional subdivision enclosing the southern and equatorial Maldives atolls, including their ocean-facing slopes, passes and lagoon reefs.	Southern reefs experience strong equatorial and open-ocean influence, high water clarity and energetic currents. Their geographic isolation and oceanographic setting distinguish them from the central and northern atolls.
Northern Bay of Bengal - Bangladesh	Bangladesh	22.8	MEOW-derived marine unit covering the southeastern Bangladesh shelf and the coral-bearing habitats around St	These marginal coral communities occur under exceptionally high river discharge, turbidity and sedimentation associated with the Ganges–Brahmaputra–Meghna system.

Ecoregion	Country/ Territory	Coral reef area (km^2)	Boundary description	Justification
			Martin's Island and adjacent waters.	This setting is markedly different from clearer-water oceanic reefs elsewhere in the region.
South Coast of India	India	128.2	Marine polygon along the southern Indian shelf, including the coral-reef habitats of the Gulf of Mannar and adjacent southern coastal waters. It is separated from the West Coast of India and Sri Lankan units.	Reefs occur in shallow, monsoon-influenced waters with substantial sediment input and close association with seagrass and other coastal habitats. Their continental-shelf setting distinguishes them from Lakshadweep and Sri Lankan reefs.
Sri Lanka East	Sri Lanka	367.0	Regional subdivision extending along the eastern Sri Lankan shelf and adjoining offshore reef habitats, bounded by the northern and southern Sri Lankan units.	Eastern reefs experience northeast-monsoon exposure, seasonal oceanographic variability and generally stronger influence from the Bay of Bengal. Their exposure and reef assemblages differ from those of western and southern Sri Lanka.
Sri Lanka North	Sri Lanka	178.5	Regional subdivision covering northern Sri Lanka, including shallow reef habitats associated with the Palk Strait, Palk Bay and adjoining northern waters.	These reefs occur in shallow, relatively enclosed and often turbid waters influenced by monsoon variability and exchange with the southern Indian shelf. Their environmental setting differs from Sri Lanka's open-ocean eastern and southern reefs.
Sri Lanka South	Sri Lanka	243.2	Regional subdivision enclosing the southern Sri Lankan coast and its adjoining fringing, rocky and offshore coral habitats.	Southern reefs are comparatively exposed to open-ocean conditions, strong wave energy and clear offshore waters. Their physical exposure distinguishes them from the more sheltered and sediment-influenced northern and western reefs.
Sri Lanka West	Sri Lanka	323.5	Regional subdivision along the western Sri Lankan shelf, bounded by the northern and southern Sri Lankan assessment units.	Western reefs experience southwest-monsoon conditions, seasonal turbidity and strong coastal currents. They are also more directly exposed to densely populated coastal areas and associated land-based pressures.
West Coast of India	India	202.5	MEOW-derived unit following the western continental margin of India and its patch, fringing and platform reef habitats, while excluding the oceanic Lakshadweep atolls.	These reefs occur mainly in shallow, turbid continental-shelf waters affected by monsoon currents, river discharge and sedimentation. Their discontinuous patch-reef character differs from the oceanic atolls of Lakshadweep and the Maldives.

11.2. Methods description

Data

Geophysical and environmental data

The spatial extent of coral reef ecosystems in most ecoregions was delineated using the UNEP-WCMC global coral reef distribution dataset (WCMC008, Global Distribution of Coral Reefs, 2021, version 4.1), with country-specific refinements. For Sri Lanka, the global layer was replaced with survey data and a coral reef map curated by the IUCN Sri Lanka office and integrated into the assessment. National experts in Bangladesh contributed local information to refine reef delineation, while the Indian expert group modified the UNEP-WCMC polygons to better

represent reef distributions documented through field observations. For the Maldives, areas identified as sand habitat were removed from the global reef layer. Reef polygons were intersected with the updated South Asia ecoregion boundaries described above to assign each reef feature to a Unit of Assessment. Invalid geometries were corrected before intersection, and terrestrial portions of the ecoregions were removed using the regional coastline. Spatial data were maintained in WGS 84 for storage and mapping and transformed to WGS 84/UTM Zone 43N (EPSG:32643) for area calculations. Reef polygons were dissolved by ecoregion to estimate the total mapped reef area within each assessment unit. Regional refinement was principally applied to the boundaries and attribution of reef polygons; national monitoring locations were used to verify site assignments.

The coastline used for clipping and cartographic presentation was developed from the Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG), with regional refinements based on Google Earth coastline information. Bathymetric context was obtained from the Global Multi-Resolution Topography (GMRT) synthesis and clipped to a buffered extent around the assessment region. Bathymetry was used to support geographic interpretation and mapping but was not used to redefine the mapped coral-reef polygons. Criterion B additionally used the reef distribution layer to calculate Extent of Occurrence and occupancy within 10 × 10 km grid cells. Criterion C used NOAA Coral Reef Watch 5-km Degree Heating Week data for 1985/1986–2025 and the projected DHW dataset of Mellin et al. (2024) for 1985–2100 under SSP2-4.5, SSP3-7.0 and SSP5-8.5. The processing and assessment of these datasets are described in greater detail under Criteria B and C.

Coral reef monitoring data

Monitoring data used for Criteria A and D included benthic-cover observations and reef-fish density and biomass records. The standardized benthic database contained 42,908 records from 559 site codes, covering 1997–2026 across the 13 Units of Assessment. It integrated five regional or national compilation datasets covering Bangladesh, Chagos, India, Maldives and Sri Lanka. Recorded benthic components included hard coral, macroalgae and other algal groups, as well as supporting substrate categories. Surveys used several established methods, including line-intercept transects, point-intercept transects, photoquadrats and image analysis, and roaming coral surveys. Some older observations were available only as published articles or reports literatures, and survey methods were not reported for a small proportion of records. All benthic observations were converted to a common data structure containing location, coordinates, survey year, reef zone, depth, method, replicate information and standardized benthic categories.

Monitoring sites were assigned to the ecoregions using their coordinates, with manual checking where location names and spatial assignment differed.

Fish information was compiled separately from 24 source files, producing 13,290 standardized family-level records from 169 ecoregion–site combinations between 1997 and 2026. Fish data were available for eight of the 13 assessment units. Surveys were predominantly conducted using underwater visual census and belt-transect methods, including fish-count and length-based biomass surveys. Where individual fish lengths were available, observations were standardized to density and biomass measures; published site or family-level biomass summaries were retained when raw observations were unavailable. Parrotfishes, primarily family Scaridae, and groupers, primarily family Serranidae, were selected as indicators of herbivory and predatory trophic processes.

Benthic and fish datasets differed in survey design, sampling effort and temporal coverage. Records were therefore harmonized to common taxonomic, spatial and measurement fields before analysis.

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 (Keith et al., 2020).

Within the GET, true photic coral reefs are classified under the ecosystem functional group 'M1.3 Photic Coral Reefs' (https://global-ecosystems.org/explore/groups/M1.3). These ecosystems are characterised by active carbonate accretion and the development of a biogenic reef framework built 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. Both true (Type A) and marginal (Type B) reefs were therefore included, recognising that marginal systems can represent dominant and ecologically important reef types in some regions. Potentially confounding ecosystem types that may host similar coral communities were excluded from the assessment. These include 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 - https://global-ecosystems.org/explore/groups/M1.6), but 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.

The occurrence and distribution of coral reef ecosystems within the region were delineated using the UNEP-WCMC global coral-reef extent layer, with country-specific refinements through the field observations and expert opinions, MEOW bioregional boundaries refined through regional expert judgement, georeferenced field observations from national and regional monitoring programmes, and published research.

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 Criterion A1, which measures the percentage of coral reef area lost across each ecoregion over the past 50 years (1975–2025). Criteria A2a, A2b or A3, requiring assessment since 1750, were not evaluated. For coral reefs, historical mapped reef area data spanning ~50 years are rarely available. In addition, coral reefs can undergo functional decline, without any visible change in the structural extent mapped by satellites. For that reason, using mapped area reduction is not possible for coral reefs. Our method uses recent hard coral cover estimates from monitoring data between 2020 – 2025 as a proxy for declines in reef area (Obura et al., 2021).

Each reef site was classified as either a functioning, net-accreting reef site or a degraded site, based on a threshold of approximately 5% hard coral cover. This threshold represents an established point where coral abundance is too low to maintain positive carbonate accretion on a reef (Perry et al., 2013). A sensitivity analysis was conducted across a range of thresholds (1–10%) to assess how results varied (Fig. 4). Each site was assumed to represent an equal portion of reef area, and the overall decline in coral reef area was estimated by calculating the percentage of monitoring sites below the coral cover threshold. We assumed that all monitored sites represented functioning coral reefs around 1975 (to assess change over the past 50 years).

For Criterion A, the standardized records produced 350 site-level baseline-to-recent comparisons while the most recent observations ranged from 2020 to 2026.

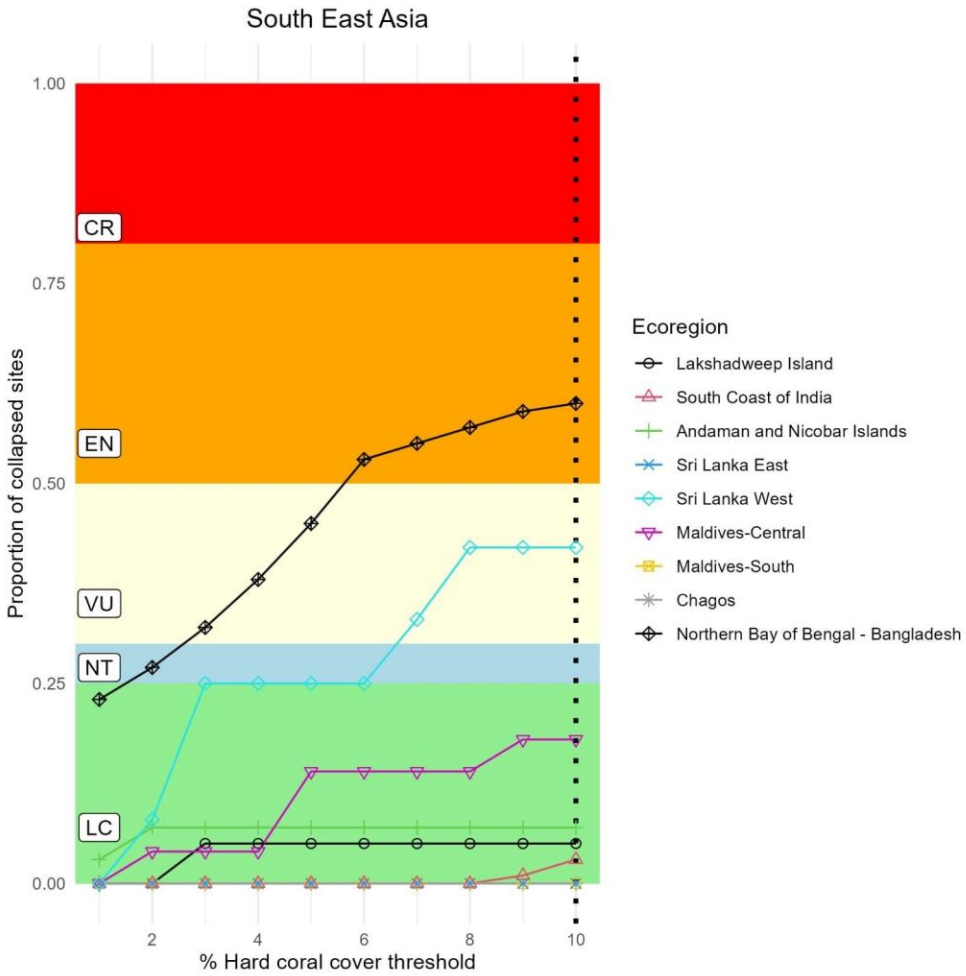


Figure 4. Sensitivity of Criterion A results to the hard-coral-cover threshold. The panels show the proportion of monitoring sites classified as collapsed across hard coral cover thresholds from 1% to 10% for South Asia overall and for each of the 13 assessed coral reef ecoregions.

Current monitoring sites were mapped against the spatial extent of coral reefs to determine the coverage and representativeness of existing monitoring efforts. Spatial representativeness was assessed by comparing the area of a polygon enclosing all monitoring sites with the total mapped Extent of Occurrence (EOO) of coral reefs within each ecoregion (see Criterion B1). To further assess data adequacy, the proportion of 10*10 km grid cells containing monitoring data was assessed relative to the total number of grid cells with coral reefs i.e. Area of Occupancy (AOO) (see Criterion B2). Expert judgment was used to evaluate whether the available data were sufficient to represent ecosystem-level decline and in cases where monitoring coverage was considered insufficient, the ecosystem was classified as Data Deficient (DD).

Table 11. A summary of the number of sites with hard coral cover data used to assess Criterion A and the data coverage across each ecoregion.

Ecoregion	Number of sites	Proportion of EOO covered	Proportion of AOO covered
Andaman and Nicobar Islands	29	2.2%	9.0%
Chagos	21	2.4%	6.5%
Lakshadweep Island	20	2.1%	25.0%
Maldives-Central	28	1.5%	2.8%
Maldives-North	2	0.0%	0.0%
Maldives-South	11	1.5%	4.1%
Northern Bay of Bengal - Bangladesh	95	44.4%	75.0%
South Coast of India	110	18.3%	77.8%
Sri Lanka East	16	11.8%	22.2%
Sri Lanka North	1	2.0%	4.5%
Sri Lanka South	2	6.2%	12.5%
Sri Lanka West	12	5.6%	12.5%
West Coast of India	3	0.1%	0.0%

The analysis contained 350 sites, of which 322 had usable geographic coordinates.

The 0% spatial coverage for Maldives-North reflects the absence of usable coordinates for its two Criterion A sites. For West Coast of India, the three sites had coordinates, but none fell within a fixed-grid cell meeting the 1% mapped-reef-area rule. These values therefore indicate a mismatch or gap in spatial coverage, not an absence of monitoring observations.

Where data were adequate, risk categories were assigned by comparing the percentage of sites with current coral cover below the collapse threshold (5%) (as an estimate for decline in extent) with the Red List of Ecosystems thresholds for Criterion A1, i.e. declines of >80%: Critically Endangered, 50–80%: Endangered, 30–50%: Vulnerable, 27–30%: Near Threatened, and <27%: Least Concern (see Table 6).

Table 12. IUCN Red List of Ecosystems Criterion A thresholds for assessing reductions in ecosystem geographic distribution.

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.

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

- Sub-criterion B1: Extent of Occurrence (EOO) – the area within the outer boundary of the ecosystem's known distribution.
- Sub-criterion 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 spatial extent of coral reef ecosystems in most ecoregions was delineated using the UNEP-WCMC global coral reef distribution dataset (WCMC008, Global Distribution of Coral Reefs, 2021, version 4.1), with country-specific refinements. For Sri Lanka, the global layer was replaced with survey data and a coral reef map curated by the IUCN Sri Lanka office and integrated into the assessment. National experts in Bangladesh contributed local information to refine reef delineation, while the Indian expert group modified the UNEP-WCMC polygons to better represent reef distributions documented through field observations. For the Maldives, areas identified as sand habitat were removed from the global reef layer.

Once validated, the coral reef extent layer was projected using WGS 84/UTM Zone 43N (EPSG:32643) for spatial analysis and reef-area calculations. It was subsequently transformed back to WGS 84 (EPSG:4326) for storage and mapping. The *makeEOO* function in the *redlistr* package (2.1.0) in R (4.5.2) 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 km^2. For Criterion B2, a 10 x 10 km grid was overlaid over the reef extent layer using the *makeAOOGrid* function, 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 14). 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 Criterion B1 or B2 for each ecoregion, experts were required to justify observed or inferred declines to reefs, or the presence of current threats, such as ocean warming, pollution, coastal development, or overfishing, that are presenting an ongoing risk to coral reefs.

Table 13. IUCN Red List of Ecosystems Criterion B thresholds for assessing reductions in ecosystem geographic distribution.

Subcriterion	*Measure of geographic distribution*	*CR*	*EN*	*VU*
B1	Area of a minimum convex polygon (km^2) enclosing all occurrences (extent of occurrence, EOO) is: **AND** at least one of the following (a–c): (a) An observed or inferred continuing decline in **ANY OF**: i. spatial extent of the ecosystem; **OR** ii. environmental quality appropriate to the characteristic biota of the ecosystem; **OR** iii. biotic interactions* appropriate to the characteristic biota of the ecosystem. (b) Observed or inferred threatening processes that are likely to cause continuing declines in geographic distribution, environmental quality or biotic interactions within the next 20 years. (c) Ecosystem exists at:	≤ 2,000 1 threat-defined location	≤ 20,000 ≤ 5 threat-defined locations	≤50,000 ≤ 10 threat-defined locations
B2	The number of 10×10 km^2 grid cells occupied (area of occupancy, AOO) are: **AND** at least one of a–c above (same as for B1).	≤ 2	≤ 20	≤ 50
B3	A very small number of threat-defined locations (generally fewer than 5) **AND** prone to the effects of human activities or stochastic events within a very short time period, and thus capable of Collapse or becoming Critically Endangered (CR) within a very short time period (B3 can only lead to a listing as Vulnerable, VU).			VU

Criterion C: Environmental Degradation

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 extreme heatwave events which cause widespread and severe coral bleaching (and mortality) have emerged as one of the biggest issues affecting coral reefs in many parts of the world, and the main threat affecting their persistence into the future (Hughes et al., 2017). This analysis is designed to capture broad-scale changes in the abiotic environment associated with increasing frequency of extreme marine heatwave events that cause coral bleaching (Emslie et al., 2024; Heron, Maynard, et al., 2016; Hughes et al., 2018), and determine how present and future environmental conditions threaten the survival and persistence of coral reef ecosystems.

Recurrent heat waves 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).

Indicator selection

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 sub-criterion C1, and
- 50 years into the future (2026–2075) for sub-criterion 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 number of severe mortality events within a 5-year 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; D. O. 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

Sub-criterion 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.

Sub-criterion 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 (Table 14). 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 . 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

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, but found this only impacted the results for one ecoregion (Lakshadweep Island).

Thresholds were established by plotting the historical DHW time series for each ecoregion and corresponding the thermal stress peaks in that record against documented coral responses. For every year in which the DHW record showed a notable peak, regional experts were asked to record whether widespread bleaching had been observed across a large proportion of the ecoregion, and whether that stress had driven significant mortality, together with supporting comment and published references where available. This drew on both the global mass bleaching events of 1998, 2010, 2016 and 2024 and on localised events documented only in regional monitoring records and literature. Separate bleaching and mortality thresholds were identified for each ecoregion and period; because the two describe different ecological outcomes, the mortality threshold is consistently the higher of the two.

Thresholds were identified by contrasting years in which widespread bleaching occurred against years in which comparable or lower thermal stress produced no such response. The lowest DHW value consistently associated with a widespread response, and above which no non-response was recorded, was taken as the minimum threshold for that period, corroborated where possible across multiple events. Where DHW in a given year substantially exceeded that threshold, bleaching was assumed to have begun once stress reached the identified threshold, with the additional accumulated heat stress contributing to greater severity and mortality rather than indicating a higher threshold for onset.

Period breakpoints were placed at the year after which the observed response to a given level of thermal stress changed, and therefore differ between ecoregions according to the timing of their documented events.

Table. 14. Evidence used to interpret the severe thermal-exposure threshold for South Asian coral reef ecoregions. For each ecoregion, documented bleaching and mortality events were compared with reconstructed Degree Heating Weeks (DHW) values to evaluate whether an operational threshold of approximately 8 DHW was appropriate for identifying severe thermal stress. Values in parentheses indicate the corresponding maximum or alternative DHW estimate used for comparison where available.

Ecoregion	Ecoregion-specific evidence and interpretation
Andaman and Nicobar Islands	Major bleaching was recorded in 2010 and 2016, when DHW reached **12.04 (12.94)** and **9.52 (10.19)**, respectively. No comparable major event was identified in 2003, when DHW remained at **3.11 (3.90)**. This supports approximately 8 DHW as a severe-event threshold for this ecoregion(Chandra Mohanty, 2017; Thinesh et al., 2025).

Ecoregion	Ecoregion-specific evidence and interpretation
Chagos	Severe bleaching and mortality occurred in 2015 at approximately **6.33 (7.74)** DHW and again in 2016 at **17.37 (18.23)** DHW. Independent field research similarly reported approximately 7.5 maximum DHW in 2015 and 17.6 in 2016. Coral cover declined by approximately 60% following the 2015 event, whereas the greater 2016 exposure caused further bleaching but proportionally less mortality among the surviving community. Thus, bleaching and mortality began near 8 DHW, while additional heat stress increased event severity (Head et al., 2019). Severe mortality was also documented after the 1998 event (Sheppard et al., 2002).
Lakshadweep Island	Severe bleaching and mortality occurred in 1998, 2010 and 2016, when maximum DHW reached **5.02**, **7.46** and **5.69**, respectively. (Dey et al., 2025) report corresponding thermal exposures of 5.3, 6.7 and 5.2°C-weeks, respectively. Their 1998–2022 monitoring across 12 sites in Agatti, Kadmat and Kavaratti documented an approximately 50% decline in mean coral cover from the 1998 baseline. Although mortality decreased with successive bleaching events, recovery was insufficient to reverse the cumulative decline, with recovery rates generally accelerating only after approximately six bleaching-free years. Responses varied with depth, wave exposure and coral composition.. These observations show that Lakshadweep can experience severe effects below 8 DHW; consequently, 8 DHW represents a conservative severe-exposure threshold rather than the biological onset of bleaching (Arthur, 2000; Yadav et al., 2018, Dey et al., 2025)).
Maldives-Central	Severe impacts occurred in 1998 and 2016, at **6.38 (6.69)** and **8.17 (8.98)** DHW. The less damaging 2010 event reached only **1.81 (2.31)**. Central Maldivian reefs experienced extensive mortality following the 1998 event and severe biological effects during 2016. This comparison supports approximately 8 DHW as a severe-event threshold while showing that bleaching can begin below it (Edwards et al., 2001; Montefalcone et al., 2020; Muir et al., 2017).
Maldives-North	Severe events in 1998 and 2016 reached **7.23 (7.54)** and **7.69 (8.49)** DHW, compared with **2.71 (3.41)** during the lower-impact 2010 event. In 2024, DHW reached **8.29 (9.15)** and moderate-to-severe bleaching was reported across Maldivian monitoring sites. These observations provide strong regional support for an operational threshold near 8 DHW (Montefalcone et al., 2020, 2026).
Maldives-South	Severe impacts occurred in 1998 and 2016 at **7.72 (8.01)** and **7.96 (8.46)** DHW, whereas the lower-impact 2010 event reached **3.67 (4.19)**. Following the 2016 event, large reductions in coral cover and reef carbonate-production capacity were documented. The comparison supports approximately 8 DHW as a severe bleaching and mortality threshold (Perry & Morgan, 2017b, 2017a).
Northern Bay of Bengal – Bangladesh	No verified peer-reviewed bleaching–mortality observation was available for direct calibration. Consequently, the regional 8-DHW threshold was transferred to this ecoregion. Exposure reached **8.87 (9.00)** in 2024, indicating severe thermal stress, but a corresponding published ecological outcome could not be confirmed. However, filed observations recorded the bleaching around the ST. Martin's Island, according to per communication of Bangladesh coral reef ecologists. This result should therefore be interpreted as exposure-based rather than locally validated.
South Coast of India	Extensive bleaching occurred in 1998 at **5.75 (5.94)** DHW, with approximately 89% of coral cover bleached and approximately 23% bleaching-related mortality in the Gulf of Mannar. Additional bleaching occurred during 2002–2003, 2010, 2016 and 2024, with the 2016 event reaching **9.35 (10.56)** DHW and causing documented mortality. The evidence shows that bleaching begins below 8 DHW but supports 8 DHW as a severe thermal-exposure threshold (Arthur, 2000; Patterson Edward et al., 2018).
Sri Lanka East	Available studies document SST variability, thermal exposure and reef condition but do not provide sufficiently matched DHW and bleaching-mortality observations for local threshold calibration. Maximum DHW was only **1.16** in 1998 and **5.32** in 2016. The regional 8-DHW threshold was therefore applied, with the result interpreted cautiously (Thilakarathne et al., 2023, 2024).
Sri Lanka North	Bleaching was reported in 1998, although reconstructed maximum DHW reached only **3.93**. In 2016 and 2024, maximum DHW reached **9.90** and **10.03**, respectively, but corresponding ecoregion-wide mortality measurements were unavailable. The regional threshold was therefore applied rather than independently calibrated (Arulananthan et al., 2021; Thilakarathne et al., 2023).
Sri Lanka South	Extensive mortality was reported during the 1998 bleaching event, despite a reconstructed maximum DHW of only **2.93**. Thermal exposure reached **10.66** in 2016, but a directly matched ecoregion-wide mortality estimate was unavailable. The disagreement between historical observations and gridded DHW prevented local calibration; therefore, the common 8-DHW threshold was retained (Arulananthan et al., 2021; Thilakarathne et al., 2023).
Sri Lanka West	Severe bleaching and mortality were documented in 1998, when reconstructed maximum DHW reached **5.54**. DHW subsequently reached **10.80** in 2016 and **9.64** in 2024, although corresponding ecoregion-wide mortality estimates were unavailable. These observations support applying the regional 8-DHW threshold with an explicit uncertainty qualification (Arulananthan et al., 2021; Thilakarathne et al., 2023).
West Coast of India	Bleaching occurred in 2010 and 2016 when DHW reached **8.03 (11.83)** and **8.58 (11.66)**. By comparison, no major event was identified in 2003, when maximum DHW was **3.01**. These observations support approximately 8 DHW as a severe-event threshold. Very high localized exposure in 2020—**11.24 (19.35)**—was associated with only limited documented mortality, illustrating that DHW represents thermal exposure and is not a deterministic predictor of mortality (Arthur, 2000; Thinesh et al., 2025).

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 sub-criteria C1 and C2 was calculated for each reef pixel using the formula:

Relative severity of decline (%) = (current conditions − initial conditions) / (collapse threshold − initial conditions) × 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 were 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 we applied a uniform initial value of 0 to all reefs, assuming that no high mortality events occurred in the 5 years around 1975. This is based on evidence that most major, widespread bleaching events started occurring in 1982/83 onwards. We also tested an initial value of one high mortality event occurring but found that this resulted in a LC assignment for ecoregions with known bleaching impacts over the past 50 years, therefore was producing inaccurate results.

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 below 5%. 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.

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 a commonly cited when predicting future reef outlooks (De Clippele et al., 2023; van Hooidonk et al., 2016; Zeng et al., 2025), however it is considered overly conservation as collapse will likely occur before we reach conditions conducive to yearly bleaching (Bland et al., 2017; D. O. Obura et al., 2021).

For the pulse pathway, the collapse threshold is defined as 2–3 severe mortality events occurring within any 5-year window. 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, specifically 2–3 extreme mortality events within a 5-year window, is required to reliably indicate conditions conducive to collapse.

Table. 14. Ecoregional DHW thresholds representing thermal stress levels resulting in widespread bleaching for the chronic pathway. Thresholds are 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	Widespread bleaching (DHW range)	Timeframe	Widespread bleaching (DHW range)
Andaman and Nicobar Islands	1985 - 2025	4	2026 - 2075	4-8
Chagos	1985 - 2025	4	2026 - 2075	4-8
Lakshadweep Island	1985 - 2025	4	2026 - 2075	4-8
Maldives-Central	1985 - 2025	4	2026 - 2075	4-8
Maldives-North	1985 - 2025	4	2026 - 2075	4-8
Maldives-South	1985 - 2025	4	2026 - 2075	4-8
Northern Bay of Bengal – Bangladesh	1985 - 2025	4	2026 - 2075	4-8
South Coast of India	1985 - 2025	4	2026 - 2075	4-8
Sri Lanka East	1985 - 2025	4	2026 - 2075	4-8
Sri Lanka North	1985 - 2025	4	2026 - 2075	4-8
Sri Lanka South	1985 - 2025	4	2026 - 2075	4-8
Sri Lanka West	1985 - 2025	4	2026 - 2075	4-8
West Coast of India	1985 - 2025	4	2026 - 2075	4-8

Ecoregion	C1—observed timeframe	C1—severe mortality thresholds (°C-weeks)	C2—projected timeframe	C2—severe mortality thresholds (°C-weeks)
Andaman and Nicobar Islands	1985–2000; 2001–2025	4; 4–5	2026–2075	8–12
Chagos	1985–2010; 2011–2025	4; 6–8	2026–2075	8–12
Lakshadweep Island	1985–2025	4	2026–2075	8–12
Maldives-Central	1985–2025	4	2026–2075	8–12
Maldives-North	1985–2025	4	2026–2075	8–12

Ecoregion	C1—observed timeframe	C1—severe mortality thresholds (°C-weeks)	C2—projected timeframe	C2—severe mortality thresholds (°C-weeks)
Maldives-South	1985–2025	4	2026–2075	8–12
Northern Bay of Bengal–Bangladesh	1985–2016; 2017–2025	4–5; 6–8	2026–2075	8–12
South Coast of India	1985–2025	4	2026–2075	8–12
Sri Lanka East	1985–2025	4	2026–2075	8–12
Sri Lanka North	1985–2025	4	2026–2075	8–12
Sri Lanka South	1985–2025	4	2026–2075	8–12
Sri Lanka West	1985–2025	4	2026–2075	8–12
West Coast of India	1985–2000; 2001–2020; 2021–2025	4; 6–8; 10–12	2026–2075	8–12

Risk status assignment

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

Where results differ between the chronic and pulse pathways, the risk category was reported based on the pathway with the greatest confidence, or a range of outcomes presented across both pathways. 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 mean decline across all combinations, while 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).

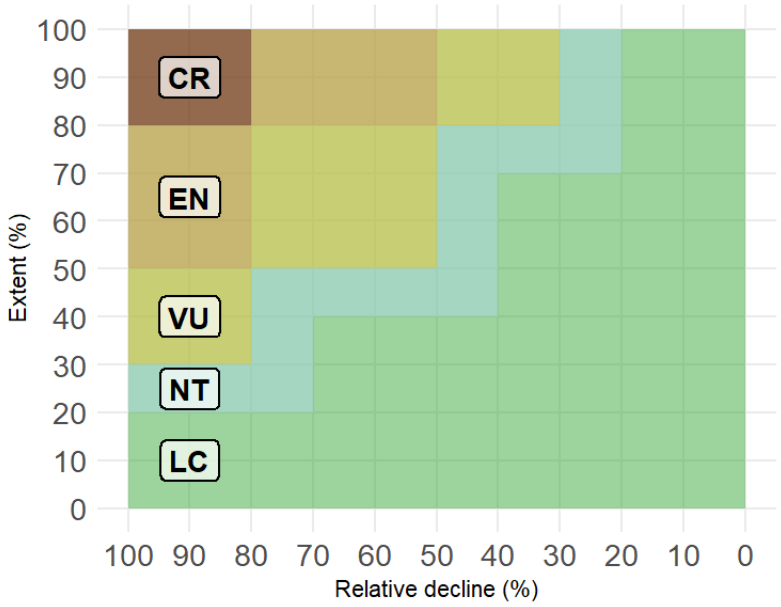


Figure 5. Classification matrix used to evaluate environmental degradation under Criterion C and disruption of biotic processes and interactions under Criterion D of the IUCN Red List of Ecosystems.

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 South Asia, three key biotic components were assessed based on previous coral reef RLEs (Bland et al. 2017, Obura et al. 2021) and using data derived from standard underwater survey methods using point intercept transects and belt transects. These components include:

- Hard corals, as the keystone ecosystem taxa responsible for forming the habitat structure and accretion processes.
- Macroalgae, as the principal competitive taxa to hard corals;
- Herbivory, providing important top-down control of algae; and
- Piscivory, which helps regulate the food web and contribute to overall ecological balance.

For each component, indicators were selected based on ecological relevance, data availability, spatial 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 state, as it has been consistently used as a key measure of reef health over several decades.

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. Algae included a mix of turf, calcareous, and fleshy algae, to account for inconsistencies in taxonomic resolution across monitoring programs. The ratio was calculated as the total algae cover divided by the sum of algae and coral cover.

For herbivory, parrotfish abundance was used as a proxy, as e.g. regional fish datasets were largely resolved at the family level and parrotfishes were among the most consistently recorded herbivores.

For piscivory, grouper abundance was selected as suitable proxy for this trophic group because e.g. they comprised the majority of piscivorous fish recorded in the available datasets, and are highly sensitive to fishing.

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 the most recent monitoring data from the last five years [2020-2025]. Chagos fish values were derived from the most recent compatible biomass dataset, collected in 2018. A *site* refers to a defined monitoring location at which transects, quadrats or other sampling units were situated and the resulting observations aggregated. Where multiple records existed for a site, the most recent annual mean value was used.

For fish related indicators, all compatible observations collected during 2020–2025 were averaged within each site. Fish density and biomass were retained as separate indicators because their units are not directly interchangeable.

Table 15. Mean current value of each biotic indicator by ecoregion. Here, *n* is the number of sites contributing to each summary.

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
Andaman and Nicobar Islands	Hard coral cover (%)	29	37.19	19.75	0.00	79.05

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
	Algae–coral ratio	67	0.579	0.405	0.000	1.000
Chagos	Hard coral cover (%)	21	29.10	11.34	11.94	63.04
	Algae–coral ratio	148	0.313	0.243	0.000	0.933
	Parrotfish biomass (kg/ha)	10	742.99	463.76	230.53	1,775.93
	Grouper biomass (kg/ha)	6	95.94	63.06	22.18	195.07
Lakshadweep Island	Hard coral cover (%)	20	36.15	16.89	2.34	57.30
	Algae–coral ratio	22	0.041	0.021	0.018	0.101
Maldives-Central	Hard coral cover (%)	28	21.79	16.20	1.50	76.30
	Algae–coral ratio	261	0.329	0.269	0.000	1.000
Maldives-North	Hard coral cover (%)	2	17.50	3.54	15.00	20.00
	Algae–coral ratio	134	0.205	0.007	0.000	0.938
Maldives-South	Hard coral cover (%)	11	28.37	14.55	13.97	64.30
	Algae–coral ratio	104	0.267	0.257	0.000	0.889
Northern Bay of Bengal – Bangladesh	Hard coral cover (%)	95	10.35	11.21	0.00	53.70
	Algae–coral ratio	128	0.836	0.168	0.000	1.000
South Coast of India	Hard coral cover (%)	110	22.18	8.71	0.50	46.60
	Algae–coral ratio	60	1.000	0.000	1.000	1.000
	Parrotfish density (individuals/ha)	24	908.38	525.40	228.33	2,147.08
	Grouper density (individuals/ha)	24	736.05	368.61	178.75	1,255.84
Sri Lanka East	Hard coral cover (%)	16	37.87	12.44	14.50	60.00
	Algae–coral ratio	34	0.135	0.225	0.000	1.000
Sri Lanka North	Hard coral cover (%)	1	11.45	n.a.	11.45	11.45
	Algae–coral ratio	11	0.667	0.330	0.154	1.000
Sri Lanka South	Hard coral cover (%)	2	17.81	3.10	15.62	20.00
	Algae–coral ratio	4	0.570	0.080	0.459	0.648
Sri Lanka West	Hard coral cover (%)	12	12.75	11.80	2.00	44.51
	Algae–coral ratio	39	0.547	0.345	0.000	1.000
West Coast of India	Hard coral cover (%)	3	15.93	4.99	12.67	21.67
	Algae–coral ratio	20	0.392	0.261	0.013	0.828

Initial values

A reference state representing conditions of each indicator approximately 50 years ago (circa 1975) was established to quantify long-term change. Initial/baseline values for hard coral cover, ACR and fish indicators were selected separately because data availability and the most appropriate method differed among ecoregions. Direct observations from the assessed ecoregion were prioritized. Where these were insufficient for hard coral cover or ACR, observations from the most ecologically similar (e.g. geographically close) ecoregions were used to supplement the available data or provide a proxy. Fish baselines were established only for Chagos and South Coast of India, where suitable reference and comparison datasets were available. Ecoregion-indicator combinations for which no defensible baseline could be established were classified as Data Deficient (DD).

Historical-condition approach

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 better condition, relatively pristine, or already degraded. Regional experts assumed that reef condition in the 1970s was generally better than at present, and that 1997/8, the year of the first widespread global bleaching event, represented a major turning point in reef condition (Souter et al., 2021; Wilkinson et al., 1999). Therefore, observations recorded in 1998 or earlier were considered potential representations of the initial condition. However, observations recorded in 1998 required additional assessment because the major coral-bleaching event occurred during that year. As most records identified only the survey year, without the precise survey date, an observation labelled 1998 could have been collected either before or after the bleaching event. The likely condition represented by the 1998 observations was therefore assessed by comparing their hard coral cover with the distribution recorded before 1998. In the Maldives dataset, the 1998 observations formed distinct low- and high-cover groups. Records with approximately 0.2–5.3% hard coral cover were considered likely to represent reefs affected by bleaching-related degradation and were excluded. In contrast, observations with more than 30% hard coral cover were within the range recorded before 1998 and were therefore considered potentially representative of conditions before the bleaching event or before substantial degradation had occurred. These observations were combined with the pre-1998 records with all site data aggregated to estimate ecoregional mean values and variance for hard coral and algae indicators.

The 1998 cut-off was retained as the general rule. Two later datasets were included only following expert review and were treated as additional evidence of historical condition rather than as a new historical period. For Andaman and Nicobar Islands, observations from 2000 were combined with observations recorded in 1998 or earlier. This grouping reflected regional expert judgement that the islands were comparatively less affected by the 1998 bleaching event and that the December 2004 Indian Ocean tsunami represented the first major disturbance within the period considered. For Sri Lanka East, the selected 2005 observation with approximately 74.25% hard coral cover was included because its high live-coral cover and low reported dead-coral and rubble contribution were considered consistent with a relatively non-degraded reef condition.

Decade-based approach

Where direct historical information was limited but sufficiently long monitoring time series were available, the highest coral cover recorded at each site was used as a proxy for its historical

reference condition. This approach assumes that the maximum observed cover provides the best available indication of the site's former condition, while recognising that monitoring may have begun after earlier degradation had already occurred. .

For hard coral cover, the highest cover among the selected observations was retained for each eligible site. The ecoregion initial value was then calculated as the mean of these site maxima. This was termed the maximum-decade approach.

For ACR, the lowest ratio among the selected observations was retained for each eligible site because a lower ACR represents a more coral-dominated condition. The ecoregion initial value was then calculated as the mean of these site minima. This was termed the minimum-decade approach and represents the ACR equivalent of the maximum-decade approach used for hard coral cover.

Fish baseline approach

Fish baselines were developed for parrotfish and groupers only. Source family names were standardized so that Scaridae and Scarinae were treated as Parrotfish, while Serranidae and Epinephelidae were treated as Grouper. The baseline and current-condition metric was selected separately for each ecoregion according to the available comparable data.

For Chagos, the Initial values for Parrotfish and Grouper were adopted from the Western Indian Ocean Red List of Ecosystem Assessment (D. Obura et al., 2021). These biomass baselines were derived from the Samoilys 2014 dataset.

For the South Coast of India, density was used to assess parrotfish and groupers. Regional experts considered fishing pressure on exploited fish groups to have been lower in the 1970s, with correspondingly higher abundance than under current conditions. In the absence of direct historical observations, sites around Kariyachalli Island, within the no-go, no-take Gulf of Mannar Marine National Park, were selected as a spatial reference. Their protected status and high fish abundance were considered to provide a proxy for conditions under reduced fishing pressure. The reported mean density and standard deviation from 2015 were adopted as the reference values, while observations from 2020–2025 represented current conditions. The 2015 survey was selected because it provided the earliest suitable density estimates for the reference sites, including both mean values and standard deviations. .

Use of supplementary data for baseline selection

A baseline was first estimated using observations from the assessed ecoregion. Where these were insufficient, supplementary data were considered in the following order:

Nearby-ecoregion proxy: A supported baseline from a geographically and ecologically comparable nearby ecoregion was assigned to the assessed ecoregion.

Pooled regional baseline: Where no suitable nearby-ecoregion baseline was available, observations from selected ecoregions were pooled. For hard coral cover, the pool included selected historical observations representative of initial conditions. For ACR, historical site means were combined with minimum-decade values from eligible long-term sites. Where a site occurred in both ACR datasets, the historical mean was retained and the minimum-decade value excluded, ensuring each site contributed only once.

Following expert review of the available data and the results produced by the alternative approaches tested, the most appropriate baseline approach was selected for each ecoregion and indicator, as summarized in Table 17.

Table 17: Baseline approaches selected for hard coral cover, ACR and fish in each South Asia coral reef ecoregion. DD indicates Data Deficient.

Ecoregion	Hard coral initial approach	ACR initial approach	Fish baseline approach
Lakshadweep Island	Historical-condition approach combining Lakshadweep observations from 1998 or earlier with Maldives observations before 1998 and selected potentially non-degraded Maldives observations in 1998	Historical-condition approach using paired algae and hard coral observations from Lakshadweep recorded in 1998 or earlier	DD: no supported enough fish data for this assessment.
South Coast of India	Maximum-decade approach applied directly to South Coast of India sites	Minimum-decade approach applied directly to paired algae and hard coral observations from South Coast of India sites	2015 density mean and reported SD from Kariyachalli Island, selected on expert recommendations as the reference within the no-go, no-take GOMMNP because it recorded higher fish abundance than the other 20 islands.
Chagos	Historical-condition approach combining Chagos observations from 1998 or earlier with Maldives-South observations before 1998 and selected potentially non-degraded Maldives-South observations from 1998	Combined regional ACR proxy using pooled historical site means and minimum-decade site values from eligible long-term sites; overlapping sites were counted once	WIO RLE 2019 (Obura et al., 2022) biomass baseline for Parrotfish and Grouper dataset.
Maldives-Central	Historical-condition approach using Maldives-Central observations before 1998 and selected potentially non-degraded Maldives-Central observations from 1998	Combined regional ACR proxy using pooled historical site means and minimum-decade site values from eligible long-term sites; overlapping sites were counted once	DD: no supported enough fish data for this assessment.
Maldives-South	Historical-condition approach combining observations from the Maldives ecoregions before 1998 with selected potentially non-degraded Maldives observations from 1998	Combined regional ACR proxy using pooled historical site means and minimum-decade site values from eligible long-term sites; overlapping sites were counted once	DD: no supported enough fish data for this assessment.
Sri Lanka West	South Coast of India maximum-decade estimate used as a proxy	South Coast of India minimum-decade ACR estimate used as a proxy	DD: no supported enough fish data for this assessment.
Andaman and Nicobar Islands	Historical-condition approach combining Andaman and Nicobar Islands observations from 1998 or	Combined regional ACR proxy using pooled historical site means and minimum-decade site	DD: no supported enough fish data for this assessment.

Ecoregion	Hard coral initial approach	ACR initial approach	Fish baseline approach
	earlier with its reviewed 2000 observations	values from eligible long-term sites; overlapping sites were counted once	
West Coast of India	**DD:** no adequate historical observations	**DD:** insufficient paired historical algae and hard coral observations	DD: no supported enough fish data for this assessment.
Northern Bay of Bengal	**DD:** insufficient historical information to establish a supported initial value	**DD:** insufficient paired historical algae and hard coral observations	DD: no supported enough fish data for this assessment.
Maldives-North	**DD:** the available 1998 observations appeared degraded, and no supported initial value could be established	**DD:** historical algae observations were unavailable	DD: no supported enough fish data for this assessment.
Sri Lanka East	Pooled regional historical-condition approach excluding Maldives-North and Northern Bay of Bengal; includes selected potentially non-degraded Maldives observations from 1998, Andaman and Nicobar Islands observations from 2000, and the reviewed Sri Lanka East observation from 2005	Combined regional ACR proxy using pooled historical site means and minimum-decade site values from eligible long-term sites; overlapping sites were counted once	DD: no supported enough fish data for this assessment.
Sri Lanka North	**DD:** no adequate historical observations	**DD:** insufficient paired historical algae and hard coral observations	DD: no supported enough fish data for this assessment.
Sri Lanka South	**DD:** insufficient historical information to establish a supported initial value	**DD:** insufficient paired historical algae and hard coral observations	DD: no supported enough fish data for this assessment.

Table 18(a). Mean initial values with variance measures for hard coral cover for each ecoregion (n = number of contributing sites)

Ecoregion	Mean (%)	Std. dev.	Min (%)	Max (%)	n
Andaman and Nicobar Islands	54.01	12.53	26.94	73.49	26
Chagos	48.27	15.72	23.00	65.00	7
Lakshadweep Island	41.42	16.56	2.00	82.00	27
Maldives-Central	46.56	15.19	27.00	82.00	17
Maldives-North	n.a.	n.a.	n.a.	n.a.	n.a.
Maldives-South	43.95	17.15	2.00	82.00	21
Northern Bay of Bengal – Bangladesh	n.a.	n.a.	n.a.	n.a.	n.a.
South Coast of India	40.17	11.20	14.49	62.71	110
Sri Lanka East	48.90	16.66	7.00	82.00	66
Sri Lanka North	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka South	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka West	40.17	11.20	14.49	62.71	110
West Coast of India	n.a.	n.a.	n.a.	n.a.	n.a.

Table 18(b). Mean initial values with variance measures for algae–coral ratio for each ecoregion (n = number of contributing sites)

Ecoregion	Mean ACR	Std. dev.	Min ACR	Max ACR	n
Andaman and Nicobar Islands	0.355	0.156	0.008	0.829	121
Chagos	0.355	0.156	0.008	0.829	121
Lakshadweep Island	0.452	0.081	0.365	0.573	5
Maldives-Central	0.355	0.156	0.008	0.829	121
Maldives-North	n.a.	n.a.	n.a.	n.a.	n.a.
Maldives-South	0.355	0.156	0.008	0.829	121
Northern Bay of Bengal – Bangladesh	n.a.	n.a.	n.a.	n.a.	n.a.
South Coast of India	0.343	0.142	0.062	0.806	110
Sri Lanka East	0.355	0.156	0.008	0.829	121

Ecoregion	Mean ACR	Std. dev.	Min ACR	Max ACR	n
Sri Lanka North	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka South	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka West	0.343	0.142	0.062	0.806	110
West Coast of India	n.a.	n.a.	n.a.	n.a.	n.a.

Table 18(c). Mean initial values with variance measures for parrotfish (Scaridae) for each ecoregion

Ecoregion	Measurement	Mean	Std. dev.	Min	Max	n sites
Andaman and Nicobar Islands	—	n.a.	n.a.	n.a.	n.a.	n.a.
Chagos	Biomass (kg/ha)	556.46	255.14	167.79	1,000.80	13
Lakshadweep Island	—	n.a.	n.a.	n.a.	n.a.	n.a.
Maldives-Central	—	n.a.	n.a.	n.a.	n.a.	n.a.
Maldives-North	—	n.a.	n.a.	n.a.	n.a.	n.a.
Maldives-South	—	n.a.	n.a.	n.a.	n.a.	n.a.
Northern Bay of Bengal – Bangladesh	—	n.a.	n.a.	n.a.	n.a.	n.a.
South Coast of India	Density (individuals/ha)	1,393.33	278.76	1,040.00	1,760.00	1[1]
Sri Lanka East	—	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka North	—	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka South	—	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka West	—	n.a.	n.a.	n.a.	n.a.	n.a.
West Coast of India	—	n.a.	n.a.	n.a.	n.a.	n.a.

Table 18(d). Mean initial values with variance measures for groupers (Serranidae) for each ecoregion

Ecoregion	Measurement	Mean	Std. dev.	Min	Max	n sites
Andaman and Nicobar Islands	—	n.a.	n.a.	n.a.	n.a.	n.a.
Chagos	Biomass (kg/ha)	228.48	148.68	30.73	547.11	13
Lakshadweep Island	—	n.a.	n.a.	n.a.	n.a.	n.a.
Maldives-Central	—	n.a.	n.a.	n.a.	n.a.	n.a.
Maldives-North	—	n.a.	n.a.	n.a.	n.a.	n.a.
Maldives-South	—	n.a.	n.a.	n.a.	n.a.	n.a.
Northern Bay of Bengal – Bangladesh	—	n.a.	n.a.	n.a.	n.a.	n.a.
South Coast of India	Density (individuals/ha)	1,533.33	522.56	880.00	2,240.00	1[1]
Sri Lanka East	—	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka North	—	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka South	—	n.a.	n.a.	n.a.	n.a.	n.a.
Sri Lanka West	—	n.a.	n.a.	n.a.	n.a.	n.a.
West Coast of India	—	n.a.	n.a.	n.a.	n.a.	n.a.

[1] South Coast of India was represented by one reference site, Kariyachalli. Its mean, standard deviation, minimum and maximum were calculated from six fish-count transects conducted in 2015.

Collapse thresholds

Collapse thresholds were defined for each Criterion D indicator as bounded values representing the point at which a defining biotic component or ecological process would be considered effectively lost, resulting in a fundamental transformation of ecosystem identity, structure or function. This follows IUCN Red List of Ecosystems guidance, which treats collapse as the loss of an ecosystem's defining features and characteristic biota (IUCN, 2024).

For benthic indicators, the thresholds represent the loss of coral-dominated reef structure and, in the case of the algae-to-coral ratio, a transition towards strong algal dominance. For fish indicators, the thresholds represent severe depletion of key functional groups and the associated

loss of herbivory by parrotfish and piscivory by groupers. Threshold selection was informed by published studies, regional empirical observations and expert judgement. The same numerical thresholds were applied consistently across all ecoregions for which comparable data were available, while the approved ecoregion-specific baselines and proxy-baseline decisions were retained. Ecoregions lacking adequate baseline or current data were classified as Data Deficient (DD).

For hard coral cover, a collapse threshold of 5% was applied, following the coral-reef RLE methodology developed for the Western Indian Ocean (D. Obura et al., 2021). This value represents a state in which reef-building corals have been reduced to very low levels and their role as ecosystem engineers is severely diminished. It should not be described as the precise minimum coral cover required to sustain positive carbonate accretion because carbonate budgets vary among reef systems. For example, research in the Caribbean identified approximately 10% coral cover as an important boundary for maintaining positive net carbonate production. Therefore, the 5% value used here represents a conservative collapse-level endpoint below this broader functional boundary.

For the algae-to-coral ratio, a collapse threshold of 0.833 was used meaning that algae cover is approximately five times hard-coral cover. This represents a severe algae-dominated state and follows the published Western Indian Ocean RLE methodology. It is treated as a collapse-level threshold rather than an early-warning threshold.

For fish indicators, collapse thresholds were defined relative to the estimated initial condition. Collapse was set at 10% of baseline parrotfish abundance or biomass and 20% of baseline grouper abundance or biomass. These thresholds serve as operational indicators of severe depletion and the corresponding disruption of herbivorous and piscivorous functions. Relative thresholds were used because fish data were expressed as biomass in Chagos and density in South Coast of India. Fish indicators were assessed only where compatible baseline and current data were available; no fish proxy baselines were assigned to other ecoregions.

Calculating relative severity of decline

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

$$\textit{relative severity of decline}\ (\%) = 100 \times \frac{initial\ value - current\ value}{initial\ value - collapse\ threshold}$$

Uncertainty in initial conditions was incorporated by applying a bootstrapping approach. For each ecoregion and indicator, initial values were represented as a normal distribution defined by the estimated mean, standard deviation, and observed range (min and max). 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 X), with the ecosystem extent calculated as the proportion of sites exceeding decline thresholds (≥20%, ≥30%, ≥50%, ≥70%, ≥80%, and 100% decline). This process was repeated **[750]** 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 ≥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. Algae to coral ratio (competitive dynamics);
3. Herbivorous fish (algal control);
4. Piscivorous fish (trophic regulation).

The assessment used the coral condition as the baseline classification. At each subsequent step, the overall risk category was increased by one level if the next indicator was classified at a higher risk level than the cumulative status to that point. This approach ensures that hard coral, as the foundational component of reef ecosystems, had the greatest influence on the final classification, while still accounting for the contribution of other biotic components. It also prevented the overall assessment from being disproportionately driven by secondary indicators (e.g. fish).

Overall risk status

Once all applicable RLE criteria and sub-criteria 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. This approach

ensures that any severe risk which may drive collapse is not diluted or overlooked in the final assessment.

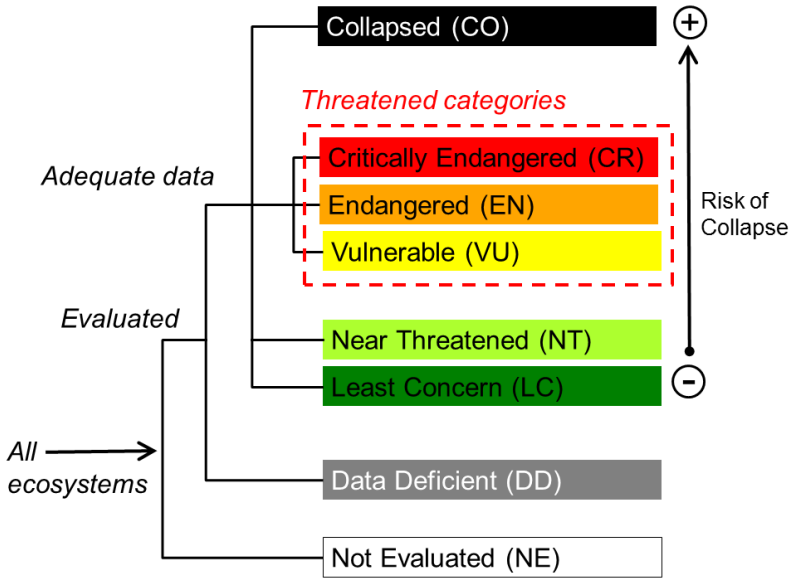


Figure 6. IUCN Red List of Ecosystems categories and assessment pathway. All ecosystem types are evaluated against the assessment criteria and assigned to one of eight categories. Ecosystems with adequate data are classified as Collapsed (CO), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), or Least Concern (LC), according to their estimated risk of ecosystem collapse.

11.3. Discussion

This assessment indicates that risk of ecosystem collapse is widespread across the assessed coral reefs of South Asia. All 13 ecoregions were classified in a threatened category overall: two were Critically Endangered (CR), four Endangered (EN) and seven Vulnerable (VU). This does not mean that all reefs are presently in the same ecological condition. Rather, the pattern results from different combinations of small geographic range, observed thermal exposure and disruption of biotic components, with the overall category determined by the highest applicable result. Criterion B was the most pervasive determinant: it equalled the Overall category in 11 ecoregions and was a sole or joint driver in each of those cases. The two exceptions were Andaman and Nicobar Islands, where Criterion C1 determined the EN status, and Chagos, where Criteria C1 and D jointly produced EN.

The prominence of Criterion B is important for interpretation. Twelve ecoregions were threatened under this criterion, including the two CR units, Northern Bay of Bengal - Bangladesh and Sri Lanka South. Their classifications indicate high susceptibility because a spatially concentrated disturbance could affect a large proportion of a restricted ecosystem; they do not, by themselves, demonstrate uniformly poor present condition (IUCN, 2024). Elevated risk was concentrated in small, geographically bounded reef systems around Sri Lanka and Bangladesh,

while the extensive Andaman and Nicobar Islands unit was Least Concern (LC) under both B1 and B2. Restricted range was not confined to mainland-associated reefs, however, because the Maldivian units, Chagos and Lakshadweep Island were also VU under B1 or B2. Subdivision into distinct units therefore exposed vulnerability that would be obscured by treating South Asian reefs as a single distribution.

Criterion A produced a much more spatially concentrated signal. Seven ecoregions were LC, while Northern Bay of Bengal - Bangladesh was VU and Sri Lanka West was NT. These results should not be interpreted as direct measurements of mapped reef-area loss over 1975–2025, because hard-coral cover was used as a proxy for local functional loss. The sensitivity analysis supports the LC result for 11 ecoregions across thresholds from 1% to 10%, but the categories for Bangladesh and Sri Lanka West changed with the threshold. Naturally low-cover or marginal reef settings may therefore be represented poorly by one common coral-cover boundary.

Observed abiotic degradation under Criterion C1 was geographically heterogeneous. Six ecoregions were EN, West Coast of India was VU and six were LC. All threatened C1 outcomes were driven by acute clustering of events exceeding 8°C-weeks within five-year windows; the chronic return-interval components remained LC. Moreover, under the 12°C-week acute sensitivity, only Chagos remained threatened, at VU. The final C1 map therefore identifies where the selected severe-heat threshold was repeatedly exceeded, not every location that experienced consequential bleaching. This distinction helps explain apparently surprising LC outcomes in Lakshadweep Island and the Maldivian units despite documented mortality in 1998 and/or 2016 and heterogeneous subsequent recovery (Arthur, 2000; Donati et al., 2025; Tamelander & Rajasuriya, 2008). Conversely, EN results in Chagos and three Sri Lankan units are consistent with evidence of repeated thermal disturbance and spatially variable warming around the region (Sheppard et al., 2002, 2020; Thilakarathne et al., 2023a).

The projected C2 results convey a different, future-facing signal. Across both pathways and all three modelled scenarios, all ecoregions were projected as CR during 2026–2075. Nevertheless, their consistency suggests that shortening recovery intervals could become a dominant future threat. This accords with global projections of earlier, longer and more severe bleaching exposure, although magnitude and timing vary spatially (Mellin et al., 2024). The contrast with C1 shows why observed degradation and modelled exposure must be reported separately.

Biotic indicators provided a more incomplete but ecologically differentiated picture. Criterion D was assessable in eight ecoregions, four of which were threatened; five were Data Deficient (DD). Threatened results were associated with hard-coral degradation in Maldives-Central, South

Coast of India and Sri Lanka West, and with grouper depletion in Chagos and South Coast of India. The algae–coral ratio did not exceed Near Threatened. Fish comparisons were possible only in Chagos and South Coast of India, but groupers had higher categories than parrotfish in both. This resembles the Western Indian Ocean RLE, where piscivore depletion was often the stronger biotic signal (Obura et al., 2021). Contrasting categories indicate that benthic and trophic processes need not deteriorate synchronously.

At the regional scale, the assessment is consistent with long-standing evidence of interacting global and local pressures. GCRMN analyses documented substantial global coral loss after 2009 and, in South Asia, losses associated with the 1998 bleaching event, partial recovery and renewed decline after 2016 (Souter et al., 2021). Earlier regional synthesis likewise described patchy post-1998 recovery and stronger direct human pressures near dense populations (Tamelander & Rajasuriya, 2008). This assessment extends that evidence by separating mechanisms: restricted distribution dominated final categories, acute heat exposure affected a different subset, and hard-coral or grouper decline added biotic evidence. Runoff, sedimentation, sewage, coastal development and fishing are plausible contributors but were not tested directly here; their regional relevance is supported by published evidence, which also identifies major observational gaps (Rajasuriya et al., 1995; Painter et al., 2023). Monsoon exposure, turbidity, currents, depth and reef setting may also help explain variation, but remain hypotheses (Ellepola et al., 2021; Donati et al., 2025).

Several limitations materially affect confidence and comparability. Monitoring coverage was uneven in space and time, and some Criterion A results were based on only one to three sites or negligible coverage of reef-occupied grid cells. Criterion A assumed that monitored sites represented functioning reefs in 1975, although baseline observations were much more recent, and no permanently lost sites were added; these assumptions could respectively inflate decline in naturally low-cover settings or underestimate losses absent from current monitoring. Criterion D sometimes relied on pooled or neighbouring-ecoregion baselines, while fish data were assessable in only two units and combined different survey designs and metrics. Hard-coral cover and algae–coral ratio are broad indicators that do not resolve community composition, structural complexity, recruitment, functional diversity or species turnover, potentially concealing ecological erosion before cover-based thresholds are crossed. The common DHW thresholds, approximately 50-km climate projections, adaptation assumptions and scenario selection may obscure fine-scale refugia or local sensitivity. Finally, DD denotes insufficient evidence, not low risk, and conclusions do not extend to Eastern Coast of India or Northern Bay

of Bengal - Myanmar, which were excluded from the final assessment. These caveats do not remove the regional risk signal, but they require the categories to be read as evidence-based estimates with unequal certainty rather than deterministic forecasts of present condition or time to collapse.

The Vulnerable classification for West Coast of India, compared with Endangered for South Coast of India, should therefore be interpreted cautiously: expert reviewers considered western reefs at least as degraded, and differences in monitoring coverage, historical baselines and assessable indicators limit direct comparisons of reef condition between these ecoregions. The categories also do not fully resolve differences in climate vulnerability or the consequences of losing ecosystem functions and services, particularly carbonate accretion supporting the persistence of oceanic reef islands such as Lakshadweep and the Maldives.

11.4. Criterion C – Environmental Degradation: supplementary figures

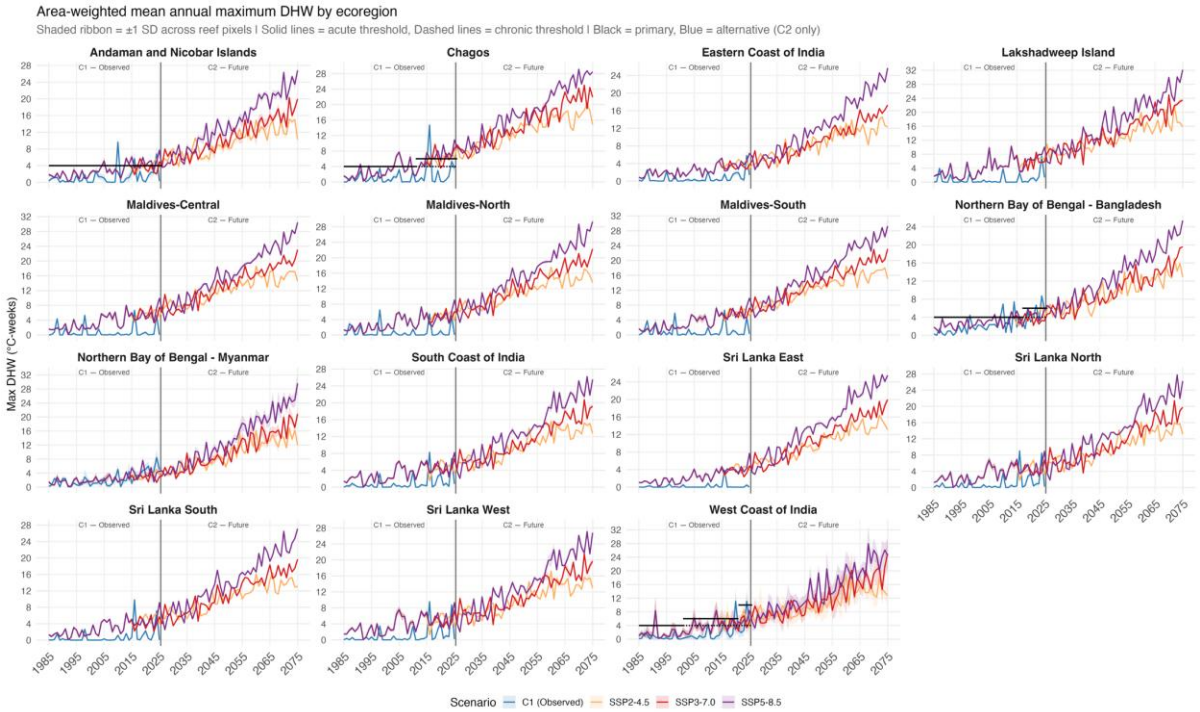


Figure S1. Annual maximum Degree Heating Weeks (DHW) averaged across coral reefs within each ecoregion from 1985-2075 for four trajectories: observed data used to assess sub-criterion C1 from 1985-2025 (blue line), and projections under three Shared Socioeconomic Pathways — SSP2-4.5 (orange), SSP3-7.0 (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.

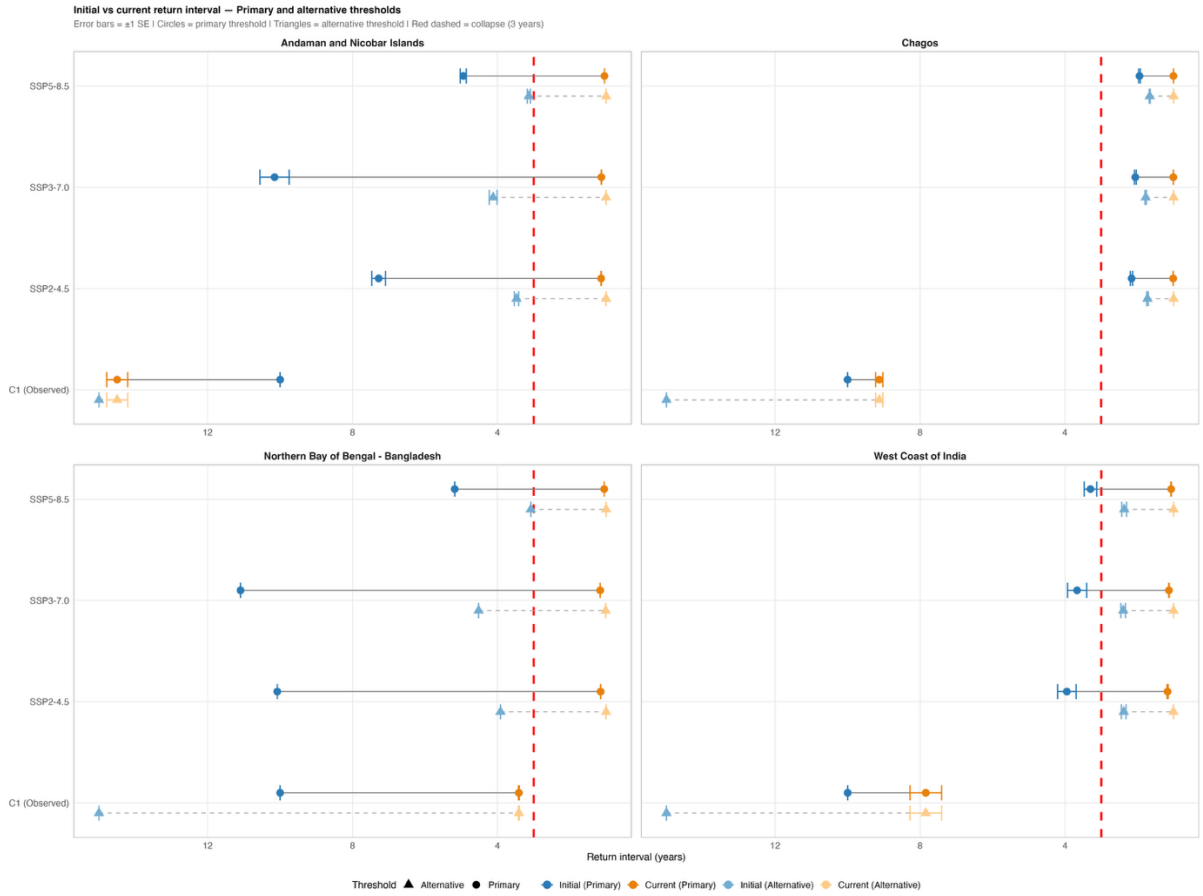


Figure S2. Change in the average return interval between severe bleaching events (years) for each ecoregion (x-axis), comparing initial conditions (blue) to current or projected future conditions (orange) across four trajectories (y-axis): observed data (C1) and projections under SSP2-4.5, SSP3-7.0, 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.

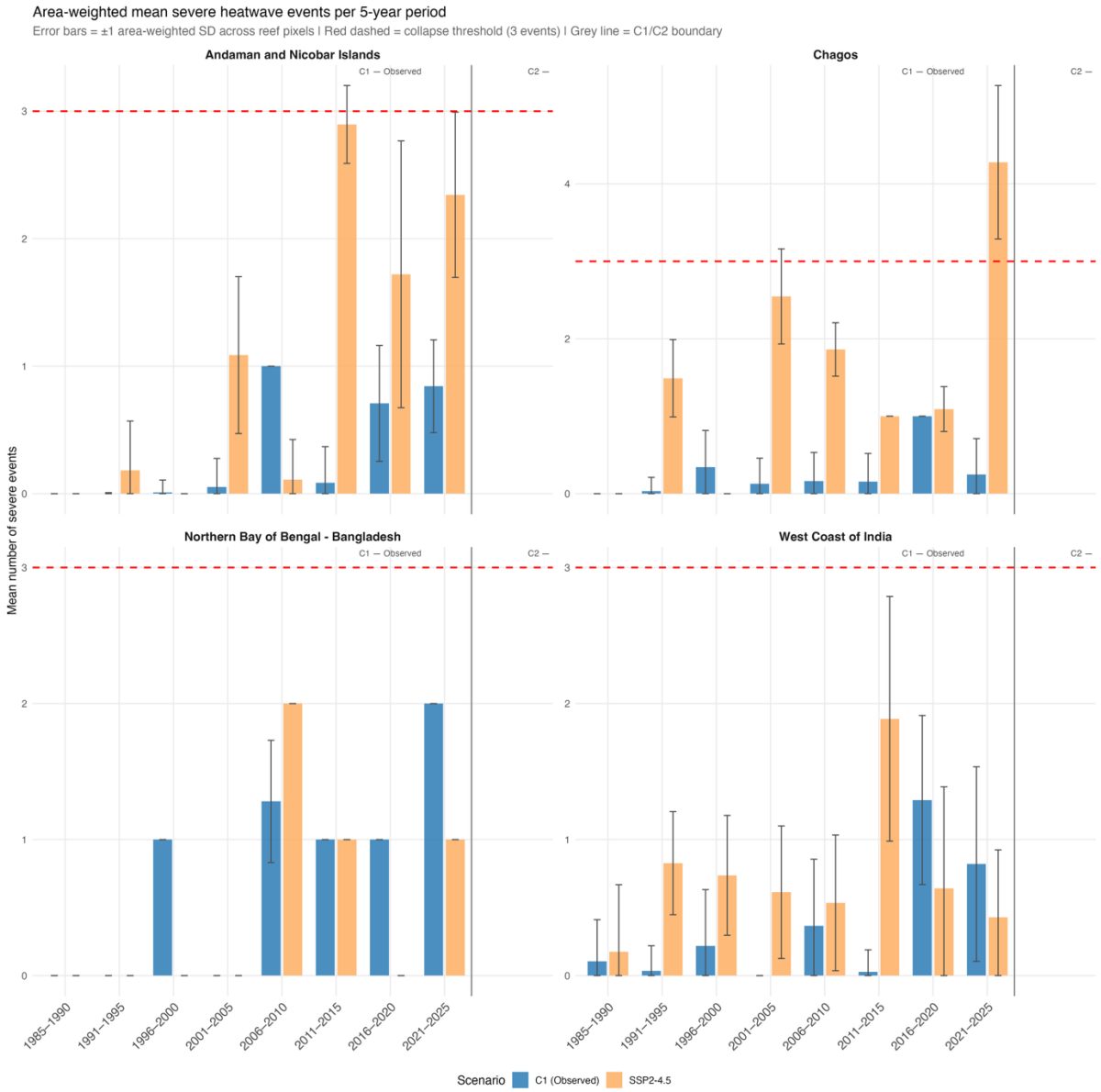


Figure S3. Mean number of severe mortality events per 5-year period, averaged across coral reef pixels within each ecoregion, under two trajectories: observed data used to assess sub-criterion C1 (blue bars, 1985–2025) and projections under SSP2-4.5 (orange bars, 1985–2075). Severe mortality events are 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.

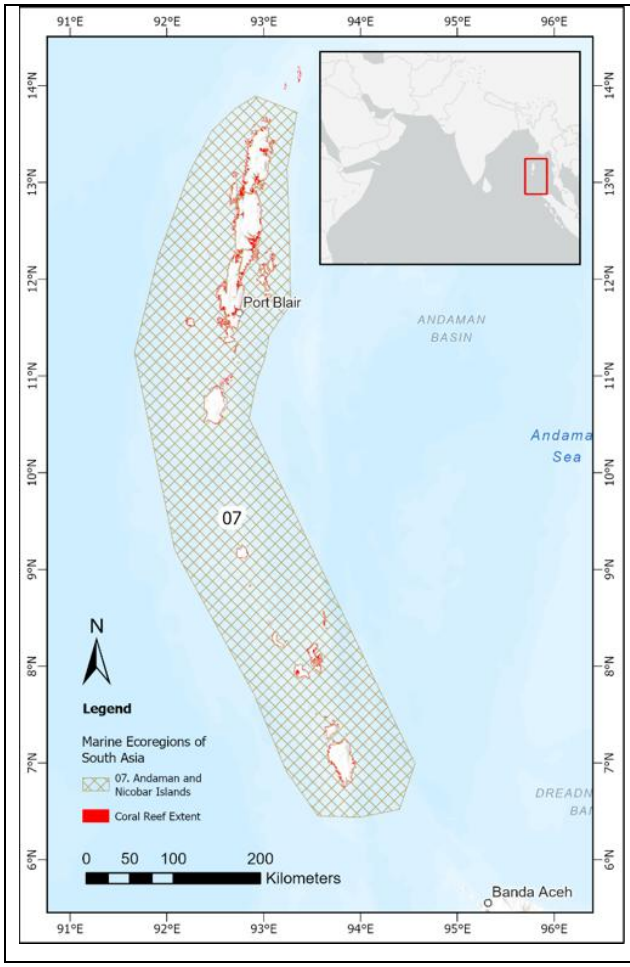
12. Appendices: Ecoregion Factsheets

11.1. Andaman and Nicobar Islands, Vulnerable (VU)

Spatial distribution

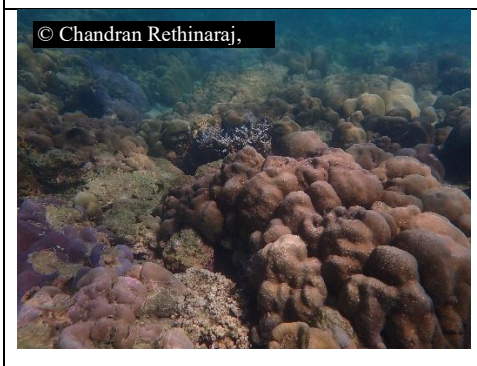
The Andaman and Nicobar Islands coral reef ecoregion extends across a long north–south archipelago in the south-eastern Bay of Bengal and Andaman Sea, approximately between 6°–14° N and 91°–94° E. Reefs occur around numerous islands from North, Middle and South Andaman to the Nicobar group. They include predominantly fringing reefs, together with patch, channel, platform and submerged reef systems and a reported barrier-reef formation extending for approximately 329 km along the western coast.

The validated spatial layer used in this assessment contains approximately 1,092.5 km^2 of mapped coral reef habitat, making this one of India's largest and most geographically extensive coral reef regions.









Ecosystem description

The Andaman and Nicobar Islands constitute a distinct coral reef ecoregion because of their oceanic-archipelago setting, extensive fringing and platform reefs, high coral diversity and strong connectivity with the eastern Indo-Pacific. The reef environment differs markedly from the more turbid continental-shelf reefs of mainland India and the northern Bay of Bengal.

The archipelago contains steep eastern island margins and broader western coral shelves, with reef flats, reef slopes, patch reefs, channel reefs, bay reefs, knolls and submerged reef systems. These habitats are influenced by seasonal monsoon circulation, oceanic currents, wave exposure and variation in terrestrial runoff. Mangroves and other coastal habitats are closely associated with many reef systems.

The ecoregion supports diverse scleractinian coral assemblages, including major reef-building genera such as *Acropora*, *Porites*, *Favia*, *Favites*, *Goniastrea*, *Montipora* and *Pocillopora*, as well as diverse reef fishes, sea turtles, reef-associated invertebrates and sharks. Important pressures include marine heat stress and coral bleaching, cyclone and storm exposure, the effects of the 2004 earthquake and tsunami, sedimentation and siltation, localised fishing, tourism and coastal development, pollution and outbreaks of crown-of-thorns starfish.

Eco-region	Key Biotic	Key Abiotic	Key Threats
Andaman and Nicobar Islands	High coral diversity with strong eastern Indo-Pacific affinity; diverse hard-coral, reef-fish and benthic-invertebrate assemblages; associated sea turtles and reef sharks. Important reef-building genera include *Acropora*, *Porites*, *Favia*, *Favites*, *Goniastrea*, *Montipora* and *Pocillopora*.	Oceanic archipelago in the Bay of Bengal and Andaman Sea. Habitats include fringing, platform, patch, channel, bay, knoll, reef-flat, reef-slope and submerged reefs. Environmental conditions are influenced by monsoon circulation, oceanic currents, wave exposure and variable terrestrial runoff.	Thermal stress and coral bleaching; cyclones and storms; earthquake–tsunami disturbance; sedimentation and siltation; localised fishing; tourism and coastal development; pollution and effluent discharge; and crown-of-thorns starfish outbreaks.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Thermal stress over the past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO			Baseline	Current
7.0% of 29 sites; 2 of 29 sites were at or below the threshold	213 10-km grid cells	76,611 km^2	Acute clustering of annual maximum **DHW ≥8°C-weeks**; 3,392 of 3,505 assessed cells (**96.8%**) reached the applicable 30% and 50% relative-decline classes	hard coral cover	54.01% ± 12.53 SD	37.19% ± 19.75 SD
				algae-coral ratio	0.355 ± 0.156 SD	0.579 ± 0.405 SD
				herbivore abundance	DD	DD
				piscivore abundance	DD	DD

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the Andaman and Nicobar Islands was assessed as Vulnerable (VU). The Overall category was determined by Criterion C1, which produced the highest applicable category in the final synthesis:

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	LC	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1970)	Future or any 50y period	Historical (1750)
	VU	CR	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1970)	Future or Any 50y period	Historical (1750)
	NT	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

The Vulnerable (VU) overall category is driven by observed acute thermal degradation under Criterion C1. Severe thermal-stress events exceeding the adopted 8°C-week DHW threshold occurred sufficiently frequently and extensively to meet the EN threshold. Major bleaching was documented in 2010 and 2016, when the 95th-percentile DHW reached approximately 12.04 and 9.52°C-weeks, respectively (Chandra Mohanty, 2017; Thinesh et al., 2025). However, the C1 result was sensitive to the thermal threshold: applying the higher 12°C-week threshold reduced the acute category to LC. The category should therefore be interpreted as evidence of widespread exposure to the assessment's operational severe-heat threshold rather than as evidence that all reefs have already collapsed.

Criterion A1 was LC because only 7% of the 29 assessed sites were at or below the 10% hard-coral-cover threshold. This result remained LC throughout the 1–10% threshold-sensitivity analysis. Nevertheless, the monitoring sites covered only approximately 2.2% of EOO grid cells

and 9.0% of AOO grid cells, limiting the ability to represent conditions across the entire archipelago.

The ecoregion was LC under both B1 and B2 because of its comparatively large EOO and AOO. Criterion D1 was NT, driven by the hard-coral indicator. The algae–coral ratio was LC, while parrotfish and grouper indicators were DD because suitable fish data were unavailable. DD fish indicators must not be interpreted as evidence of low risk.

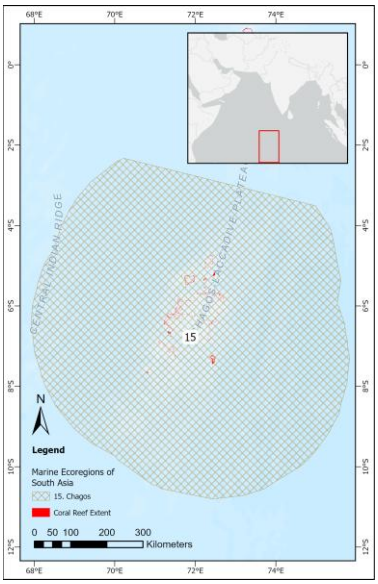
Monitoring should prioritise repeat surveys at geographically representative sites across both the Andaman and Nicobar Island groups, with standardised measurements of hard-coral cover, algae, coral recruitment, structural complexity and fish biomass. Thermal-exposure monitoring should be paired with field observations of bleaching and mortality to improve local calibration of DHW thresholds. Reducing sedimentation, pollution, damaging coastal development and unsustainable fishing may help maintain reef resilience, although the assessment did not directly quantify the contribution of these local pressures to the assigned category.

12.1. Chagos, Vulnerable (VU)

Spatial distribution (boundaries, area of coral reef)

The Chagos ecoregion encompasses the Chagos Archipelago in the central Indian Ocean, located along the Laccadive–Chagos ridge south of the Maldives. The ecoregion covers a large oceanic area, but coral reefs are concentrated within the atoll systems and submerged carbonate platforms of the archipelago.

Reefs occur as well-developed atoll rims, submerged atolls, seamounts, lagoonal patch reefs, faros, and outer reef slopes, forming a highly structured and extensive reef network. The highest reef density is found around atoll margins and within lagoon systems, while the surrounding deep ocean areas contain little to no reef habitat. The spatial pattern is characterized by isolated but highly intact reef complexes, separated by deep ocean waters. Compared with Maldives ecoregions, the Chagos reefs are more remote, less fragmented, and relatively undisturbed, with reef distribution closely tied to the geomorphology of the carbonate platforms.





Map of Chagos Ecoregion and its Structurally diverse shallow-water coral reef community in the Chagos Archipelago ecoregion, comprising massive, submassive, branching and foliose hard-coral colonies with associated reef fishes

Ecosystem description

Coral reefs in the Chagos ecoregion form one of the most remote and relatively undisturbed oceanic atoll systems in the central Indian Ocean, located along the Laccadive–Chagos ridge. The reefs are characterized by well-developed atoll rims, submerged atolls, seamounts, lagoonal patch reefs, and steep outer reef slopes, supporting high coral cover and structurally complex habitats. Coral communities are typically dominated by *Acropora*, *Porites*, *Pavona*, *Pocillopora*, and *Montipora,* with exceptionally diverse assemblages of reef fishes, invertebrates, and pelagic

species. The reefs occur in clear, oligotrophic waters with minimal terrestrial influence and strong oceanic connectivity. Compared with other South Asia ecoregions, Chagos reefs are distinguished by their isolation, high ecological integrity, and relatively low direct human pressure. However, they remain highly vulnerable to climate-induced bleaching events and ocean warming, which have caused widespread coral mortality in the past, affecting reef structure and recovery dynamics.

Eco-region	Key Biotic	Key Abiotic	Key Threats
Chagos	Highly diverse coral communities dominated by *Acropora, Porites, Pavona, Pocillopora, Montipora*, with rich assemblages of reef fishes, pelagic species (e.g., sharks, tunas), molluscs, crustaceans, and echinoderms. Reefs support high biomass and relatively intact trophic structures compared to other regions.	Remote oceanic atoll system on the Laccadive–Chagos ridge, characterized by clear oligotrophic waters, low sedimentation, and strong oceanic circulation and connectivity. Includes atoll rims, lagoon patch reefs, and steep outer reef slopes with high structural complexity.	Climate-induced coral bleaching (primary threat), driven by ocean warming. Limited direct human pressure, but fishing (historical/IUU) and potential climate-related impacts (e.g., sea-level rise, temperature anomalies) remain key concerns.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Thermal stress over the past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
0.0% of 21 sites; 0 of 21 sites were at or below the 10% hard-coral-cover threshold	**199** 10-km grid cells	**45,278 km²**	Acute clustering of annual maximum **DHW ≥8°C-weeks**; all 2,217 assessed cells (**100%**) reached the applicable 30% and 50% relative-decline classes	Hard coral cover	48.27% ± 15.72 SD (n = 7)	29.10% ± 11.34 SD (n = 21)
				Algae–coral ratio	0.355 ± 0.156 SD (n = 121)	0.313 ± 0.243 SD (n = 148)
				Herbivore abundance *(parrotfish biomass)*	556.46 ± 255.14 kg ha^{-1} SD (n = 13)	742.99 ± 463.76 kg ha^{-1} SD (n = 10)
				Piscivore abundance *(grouper biomass)*	228.48 ± 148.68 kg ha^{-1} SD (n = 13)	95.94 ± 63.06 kg ha^{-1} SD (n = 6)

Criteria Assessment

Overall, the risk of collapse of coral reefs in the Chagos ecoregion was assessed as Vulnerable (VU)**.** The Overall category was determined by Criterion C1, which were the highest applicable categories in the approved final synthesis. Criterion C2 was assessed separately but excluded from the final Criterion C and Overall categories:

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?

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
	VU	LC	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1970)	Future or any 50y period	Historical (1750)
	VU	CR	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1970)	Future or Any 50y period	Historical (1750)
		NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

Category abbreviations: CO = Collapsed; CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated

Key findings and recommendations

The Vulnerable (VU) overall category reflects two distinct processes: observed acute thermal degradation under Criterion C1 and disruption of biotic processes under Criterion D1. Criterion B1 also identified vulnerability associated with the ecoregion's restricted EOO.

Severe bleaching and mortality occurred during consecutive thermal events in 2015 and 2016. The 95th-percentile and maximum DHW values were approximately 6.33 and 7.74°C-weeks in 2015 and 17.37 and 18.23°C-weeks in 2016. Field observations recorded an approximately 60% reduction in coral cover following the 2015 event and additional bleaching in 2016, although mortality was proportionally lower among the surviving coral community (Head et al., 2019). Severe mortality was also documented following the 1998 bleaching event (Sheppard et al., 2002). These observations support the use of approximately 8°C-weeks as an operational threshold for severe thermal stress. Similarly as Andaman and Nicobar Islands, the Chagos assessment remained threatened at VU when the higher 12°C-week sensitivity threshold was applied.

Criterion A1 was LC because none of the 21 assessed sites was at or below the 10% hard-coral-cover threshold. This category was unchanged across thresholds from 1% to 10%. Nevertheless, the monitoring sites covered only approximately 2.4% of EOO grid cells and 6.5% of AOO grid cells, limiting representation of the full reef system.

Criterion D1 was EN because the grouper indicator was EN in 82.5% of uncertainty iterations. By comparison, hard coral was predominantly NT, the algae–coral ratio was consistently LC, and parrotfish was predominantly LC. The contrast between parrotfish and grouper biomass suggests that herbivorous and predatory fish functions may not have changed at the same rate. Grouper

depletion may reflect historical or ongoing fishing pressure, but this explanation was not tested directly in the assessment.

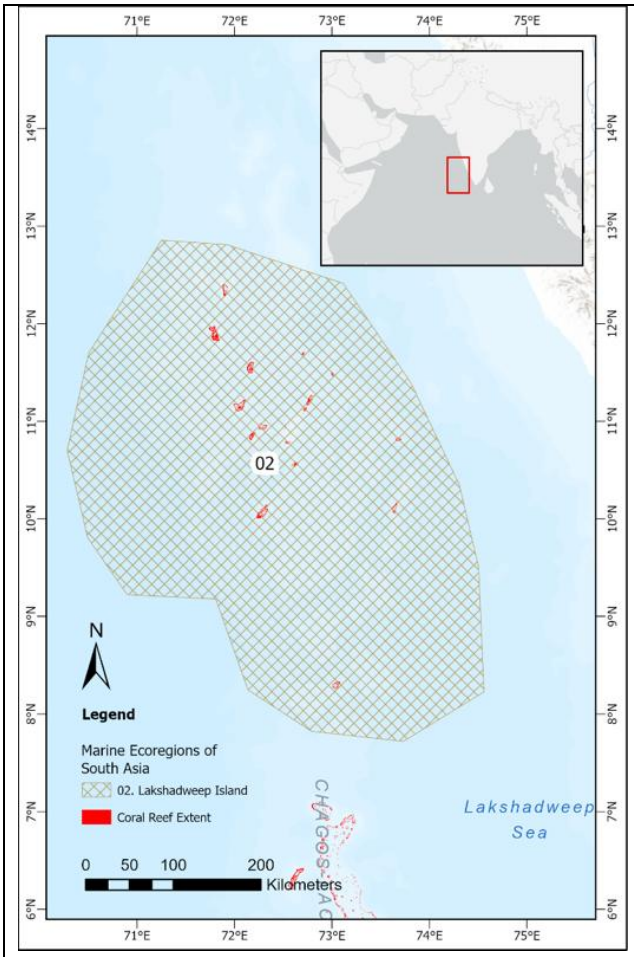
Monitoring should maintain long-term coral-cover and bleaching records while expanding geographically representative observations across atolls, submerged banks, lagoons and outer slopes. Repeated fish-biomass surveys using comparable methods are particularly important for evaluating grouper trends and distinguishing persistent trophic disruption from differences among datasets. Continued surveillance of fishing activity and protection of large-bodied predatory fishes would address the principal biotic risk signal. Because thermal stress remains the primary regional-scale pressure, local actions should be complemented by monitoring of recovery, recruitment, structural complexity and potential thermal refugia.

12.2. Lakshadweep Island, Vulnerable VU

Spatial distribution (boundaries, area of coral reef)

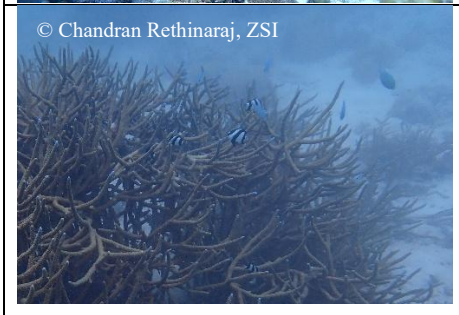
The Lakshadweep Island coral reef ecoregion comprises a dispersed chain of oceanic atolls, reefs and submerged banks in the Arabian Sea, approximately 220–440 km west of the Kerala coast. It extends roughly from 8° to 12°13′ N and 71° to 74° E and forms the northernmost part of the Laccadive–Maldives–Chagos ridge. The assessment boundary encloses the Lakshadweep atolls and their associated lagoons, reef flats, outer reef slopes and submerged reef habitats, while excluding the sediment-influenced continental reefs of the West Coast of India ecoregion.

The validated spatial layer contains approximately 436.1 km^2 of mapped coral reef habitat. Reef habitat is distributed discontinuously among individual atolls, islands and banks, separated by deep oceanic waters. Within each atoll, coral habitat is concentrated on shallow reef platforms, lagoon margins, reef crests and ocean-facing slopes.









Ecosystem description

Lakshadweep constitutes a distinct coral reef ecoregion because it is India's only extensive oceanic atoll system and differs markedly from the turbid, sediment-influenced reefs along mainland western India. The ecoregion contains shallow lagoons, reef flats, reef crests, outer reef slopes, submerged banks and associated seagrass and macroalgal habitats. Clear, saline and generally oligotrophic oceanic waters support carbonate-producing reef communities, although environmental conditions vary between sheltered lagoons and exposed outer reefs and are strongly influenced by monsoon circulation, waves and currents.

The ecoregion supports approximately 133 coral species in 44 genera and a highly diverse reef-fish assemblage. Important reef-building corals include *Acropora*, *Porites*, *Montipora*, *Pocillopora* and massive merulinid corals. Reef and lagoon habitats also support seagrasses, macroalgae, sponges, molluscs, echinoderms, marine turtles and commercially and ecologically important fishes. Lakshadweep has strong biogeographic affinities with the Maldives and other central Indian Ocean reef systems.

Recurrent thermal bleaching has been one of the most consequential disturbances. Severe bleaching and mortality were documented in 1998, 2010 and 2016, while additional thermal exposure occurred in 2024. Local pressures include fishing, tourism-related development, wastewater and solid-waste pollution, sedimentation, marine debris, coral disease, crown-of-thorns starfish predation and overgrowth by competing sponges. These pressures may reduce recovery between successive climate-driven disturbances.

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
Lakshadweep Island	Diverse reef-building coral communities, including *Acropora*, *Porites*, *Montipora* and *Pocillopora*; approximately 133 coral species in 44 genera; diverse reef fishes, seagrasses, macroalgae, sponges, molluscs, echinoderms and marine turtles.	Oceanic atoll system forming the northernmost part of the Laccadive–Maldives–Chagos ridge; clear, saline and oligotrophic waters; shallow lagoons, reef flats, crests, outer slopes and submerged banks; strong monsoonal, wave and current influence.	Recurrent coral bleaching and ocean warming; coral disease; crown-of-thorns starfish predation; competing-sponge overgrowth; fishing pressure; tourism and coastal infrastructure; wastewater, marine litter and lagoon pollution; sedimentation, shoreline erosion and seagrass decline.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
5.0% of 20 sites; 1 of 20 sites was at or below the 10% hard-coral-cover threshold	**44** occupied 10-km grid cells	**51,259 km²**	Severe bleaching was documented in 1998, 2010 and 2016, when maximum DHW reached approximately 5.02, 7.46 and 5.69°C-weeks, respectively. Maximum DHW reached 9.31°C-weeks in 2024.	Hard coral cover	41.42% ± 16.56 SD (n = 27)	36.15% ± 16.89 SD (n = 20)
				Algae–coral ratio	0.452 ± 0.081 SD (n = 5)	0.041 ± 0.021 SD (n = 22)
				Herbivore abundance	DD	DD

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
				Piscivore abundance	DD	DD

Criteria Assessment

Overall, the risk of collapse of coral reefs in the Lakshadweep Island ecoregion was assessed as Vulnerable (VU). The overall category was determined by the restricted Area of Occupancy under Criterion B2.

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

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

Key findings and recommendations

Lakshadweep Island was classified as Vulnerable, primarily because its coral reefs occupy only (44) 10-km grid cells, meeting the adopted threshold for a restricted Area of Occupancy under Criterion B2. Its EOO is comparatively extensive because the atolls are widely dispersed, but reef habitat is confined to a relatively small number of shallow atoll platforms. This spatial configuration increases vulnerability to disturbances that may affect several occupied reef cells during the same event.

Criterion A was assessed as Least Concern, with only one of 20 monitored sites at or below the 10% hard-coral-cover threshold. The result was stable across the assessed 1–10% threshold-sensitivity range. Nevertheless, monitoring sites covered only a small proportion of the EOO, so

the result should not be interpreted as demonstrating uniformly favourable reef condition across the archipelago.

Observed thermal degradation under Criterion C1 was assessed as VU under the operational regional model. However, Lakshadweep experienced substantial bleaching and mortality during 1998, 2010 and 2016 at maximum DHW values below 8°C-weeks. This indicates that the common 8-DHW threshold represents a conservative severe-exposure threshold and may not capture the biological onset of bleaching in this ecoregion. The projected C2 result indicates much greater future thermal risk.

Criterion D1 was Near Threatened**,** with both hard-coral cover and the algae–coral ratio producing modal NT classifications in the uncertainty analysis. Fish indicators remained Data Deficient because available observations could not be assessed against sufficiently supported, method-compatible baselines.

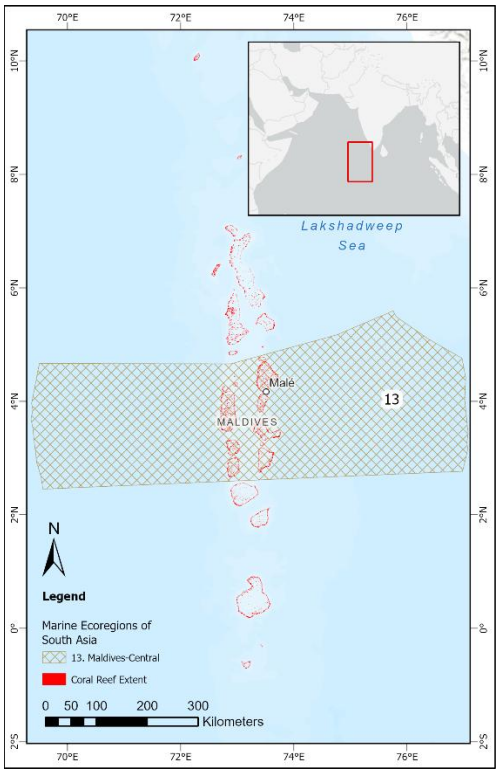
Monitoring should therefore be expanded across currently underrepresented atolls and standardised through time, particularly following thermal-stress events. Fish surveys should collect comparable abundance, body-size and survey-area information so that parrotfish and grouper biomass can be estimated. Local management should continue to reduce fishing pressure, wastewater and solid-waste pollution, tourism-related reef damage, anchoring and other chronic disturbances that may constrain recovery between bleaching events. Protection of reef–lagoon connectivity and sites demonstrating sustained coral recruitment or thermal resilience would support recovery capacity across this spatially restricted ecoregion.

12.3. Maldives-Central, Vulnerable (VU)

Spatial distribution

The Maldives-Central coral reef ecoregion covers the central portion of the Maldivian archipelago, centred around Malé and the adjoining central atoll chains. It forms part of the north–south Laccadive–Maldives–Chagos ridge in the central Indian Ocean. The assessment unit is a regional subdivision of the broader Maldives marine ecoregion and encompasses the central atolls and their associated lagoons, reef channels, submerged reefs and ocean-facing reef slopes. The validated spatial layer contains approximately 1,990.4 km^2 of mapped coral reef habitat, making Maldives-Central one of the largest coral reef assessment units in South Asia by mapped reef area. Reef habitat is concentrated along atoll rims, within lagoons and around channels and submerged carbonate platforms. Deeper oceanic waters between the atolls contain little or no shallow coral reef habitat.

Reefs occur as continuous and discontinuous atoll rims, lagoonal patch reefs, faros, pinnacles and channel-associated reef systems. The central atolls contain extensive and closely spaced reef complexes, with strong physical and ecological connections among outer reef slopes, channels and lagoonal habitats.



Ecosystem description

Coral reefs in Maldives-Central form a highly developed oceanic atoll ecosystem characterised by extensive carbonate platforms, lagoons, channels and steep outer reef slopes. The reefs develop in warm, clear and generally oligotrophic waters with limited natural terrestrial sediment input. Reef structure and ecological processes are strongly influenced by the seasonal monsoons, tidal exchange and currents flowing through the channels between the open ocean and atoll lagoons.

Coral communities include major Indo-Pacific reef-building genera such as *Acropora*, *Porites*, *Pocillopora*, *Montipora*, *Pavona*, *Cyphastrea* and massive merulinid corals. These habitats support diverse assemblages of reef fishes, sharks, rays, marine turtles, molluscs, crustaceans, echinoderms and other reef-associated organisms. The combination of outer reef slopes, channel reefs, sheltered lagoon reefs and patch reefs provides substantial environmental and structural diversity.

Maldives-Central is assessed separately from Maldives-North and Maldives-South because its large, densely distributed atolls, extensive lagoon systems, concentration of reef habitat and central position in the archipelago create a distinct geographic and oceanographic setting. The ecoregion also contains the country's greatest concentration of population, tourism infrastructure and coastal modification.

The principal regional threat is climate-induced coral bleaching. Extensive mortality occurred during the 1998 and 2016 thermal-stress events, with subsequent effects on coral cover, structural complexity and carbonate production. Local pressures include dredging, land reclamation, harbour and resort development, sewage and nutrient pollution, marine debris, anchoring, reef fishing and extraction of reef-associated species.

Ecoregion characteristics

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
Maldives-Central	Diverse Indo-Pacific reef-building coral communities, including *Acropora*, *Porites*, *Pocillopora*, *Montipora* and massive merulinid corals; diverse reef fishes, sharks, rays, turtles, molluscs, crustaceans and echinoderms. Structurally diverse habitats include atoll rims, lagoonal patch reefs, faros, channels and outer reef slopes.	Large oceanic atoll systems situated on the Laccadive–Maldives–Chagos ridge; clear, warm and oligotrophic waters; extensive lagoons and carbonate platforms; strong monsoon circulation, tidal exchange and reef-channel currents; high connectivity between lagoons and outer reefs.	Climate-induced bleaching and ocean warming; tourism and urban development; dredging and land reclamation; harbour construction and other coastal modification; wastewater and nutrient pollution; marine debris; anchoring and fishing pressure; sea-level rise and ocean acidification.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
18.0% of 28 sites; 5 of 28 sites were at or below the 10% hard-coral-cover threshold	**144** occupied 10-km grid cells	**22,195 km^2**	No primary C1 component exceeded LC. Severe impacts occurred in 1998 and 2016, when the 95th-percentile annual maximum DHW reached approximately 6.38 and 8.17°C-weeks, respectively.	Hard coral cover	46.56% ± 15.19 SD (n = 17)	21.79% ± 16.20 SD (n = 28)
				Algae–coral ratio	0.355 ± 0.156 SD (n = 121)	0.329 ± 0.269 SD (n = 261)
				Herbivore abundance	DD	DD
				Piscivore abundance	DD	DD

Only five of the 28 Criterion A sites were georeferenced sufficiently for the spatial-coverage analysis. These sites covered approximately 1.5% of EOO grid cells and 2.8% of AOO grid cells. The Criterion A result should therefore be interpreted cautiously because the monitoring records represent only a small proportion of the ecoregion's mapped distribution.

Criteria assessment

Overall, the risk of collapse of coral reefs in the Maldives-Central ecoregion was assessed as Vulnerable (VU). This category was jointly supported by the restricted Extent of Occurrence under Criterion B1 and disruption indicated by hard-coral cover under Criterion D1.

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

Abbreviations: CO = Collapsed; VU = Vulnerable; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated.

Key findings and recommendations

Maldives-Central was classified as VU under both Criterion B1 and Criterion D1. Although the ecoregion contains approximately 1,990.4 km^2 of mapped reef habitat and its AOO was assessed as LC, its EOO of 22,195 km^2 met the adopted threshold for VU when considered with continuing threats. The result reflects the geographic concentration of coral reefs within a relatively restricted central archipelago rather than an absence of extensive reef habitat.

Criterion A1 was assessed as Least Concern, with five of 28 sites at or below the 5% hard-coral-cover threshold. The classification remained LC across the assessed 1–10% threshold-sensitivity range. Nevertheless, the low spatial coverage of georeferenced monitoring sites introduces uncertainty and may obscure variation among atolls and reef zones.

Observed thermal degradation under Criterion C1 was also assessed as VU. The 1998 and 2016 events caused extensive coral mortality, and the 2016 event reached a 95^{th}-percentile annual maximum of approximately 8.17°C-weeks, with a maximum of 8.98°C-weeks. The C1 result reflects the frequency, clustering, relative severity and spatial extent rules used by the assessment rather than coral condition following any single bleaching event.

Criterion D1 was Vulnerable, driven by hard-coral cover. Current mean hard-coral cover was substantially lower than the estimated initial value, and VU was the modal result in 95.7% of uncertainty iterations. In contrast, the algae–coral ratio was NT in 98.8% of iterations. These contrasting indicators suggest that reduced coral cover has not consistently resulted in algae-dominated conditions across the ecoregion. Parrotfish and grouper indicators remained DD because method-compatible quantitative baselines were unavailable.

Monitoring should be expanded across central atolls, reef zones and depths, with coordinates retained for every site. Repeated benthic surveys should measure coral cover, community composition, recruitment, mortality, algae and structural complexity. Fish monitoring should include standardised survey area, abundance and body-size information so that biomass-based parrotfish and grouper indicators can be assessed. Local actions should limit dredging, reclamation, wastewater discharge, anchoring and unsustainable fishing, particularly at reefs supporting recruitment, connectivity or rapid post-bleaching recovery.

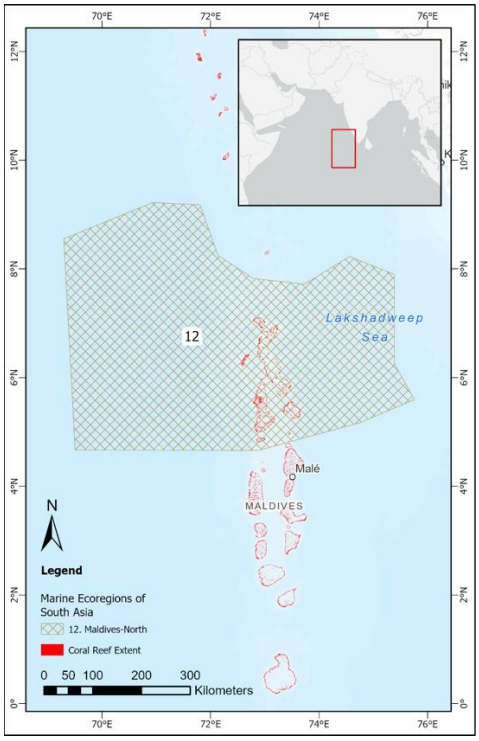
12.4. Maldives-North, Vulnerable (VU)

Spatial distribution

The Maldives-North coral reef ecoregion encompasses the northern portion of the Maldivian archipelago and its associated atolls, lagoons, reef channels and ocean-facing reef slopes. It forms part of the Laccadive–Maldives–Chagos ridge and is separated from the Maldives-Central assessment unit on the basis of its geographic position, atoll configuration and northern Indian Ocean setting.

The validated spatial layer contains approximately 1,271.8 km^2 of mapped coral reef habitat. Reefs are concentrated on shallow carbonate platforms rather than being distributed uniformly throughout the wider marine polygon. They occur principally as atoll rims, lagoonal patch reefs, faros, pinnacles, channel-associated reefs and steep outer reef slopes. Deep oceanic waters between the atolls contain little or no shallow coral reef habitat.

The distribution is characterised by clusters of reef habitat around individual atolls, with strong connections between lagoon reefs, channels and outer slopes. Although reef habitat is extensive, it is geographically confined to a relatively restricted section of the northern Maldivian ridge.



Ecosystem description

Maldives-North is an oceanic atoll ecosystem developed on submerged volcanic foundations along the Laccadive–Maldives–Chagos ridge. Its ring-shaped atolls contain shallow lagoons, reef

flats, patch reefs, faros, channels and steep ocean-facing slopes. The reefs develop in warm, clear and generally oligotrophic waters with limited natural terrestrial sediment input.

Seasonal monsoon circulation, waves, tidal exchange and currents through reef channels strongly influence water movement, sediment redistribution, larval dispersal and connectivity between lagoons and outer reefs. Environmental conditions vary among sheltered lagoon reefs, current-exposed channels and wave-exposed outer reef slopes.

Coral communities include major Indo-Pacific reef-building genera such as *Acropora*, *Porites*, *Pocillopora*, *Montipora*, *Pavona* and massive merulinid corals. These structurally diverse habitats support reef fishes, sharks, rays, marine turtles, molluscs, crustaceans, echinoderms and other reef-associated organisms.

The ecoregion is assessed separately from Maldives-Central and Maldives-South because of its northern geographic position, monsoon and circulation regime, atoll spacing and patterns of thermal exposure. Principal threats include climate-induced coral bleaching, ocean warming, tourism and coastal infrastructure, dredging and reclamation, wastewater and nutrient pollution, marine debris, anchoring and fishing pressure.

Ecoregion characteristics

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
Maldives-North	Diverse Indo-Pacific reef-building corals, including *Acropora*, *Porites*, *Pocillopora* and *Montipora*; diverse reef fishes, sharks, rays, marine turtles, molluscs, crustaceans and echinoderms. Habitats include atoll rims, lagoonal patch reefs, faros, channel reefs and outer reef slopes.	Northern oceanic atolls situated on the Laccadive–Maldives–Chagos ridge; clear, warm and oligotrophic waters; limited natural terrestrial sediment input; strong monsoon circulation, tidal exchange and channel currents; connectivity between lagoons and ocean-facing reefs.	Climate-induced bleaching and ocean warming; tourism development; dredging, reclamation and other coastal modification; wastewater and nutrient pollution; marine debris; anchoring and fishing pressure; sea-level rise and ocean acidification.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
0.0% of 2 sites; neither site was at or below the 10% hard-coral-cover threshold	133 occupied 10-km grid cells	22,842 km^2	No primary C1 component exceeded LC. The 95th-percentile annual maximum DHW reached approximately 7.23°C-weeks in 1998, 7.69°C-weeks in 2016 and 8.29°C-weeks in 2024.	Hard coral cover	DD	17.50% ± 3.54 SD (n = 2)
				Algae–coral ratio	DD	0.205 ± 0.007 SD (n = 2)
				Herbivore abundance	DD	DD
				Piscivore abundance	DD	DD

Neither of the two Criterion A monitoring sites had coordinates suitable for the spatial-coverage analysis. Consequently, the estimated coverage was 0% of EOO grid cells and 0% of AOO grid

cells. The Criterion A result is therefore highly uncertain and should not be interpreted as representative of the entire ecoregion.

Criteria assessment

Overall, the risk of collapse of coral reefs in the Maldives-North ecoregion was assessed as Vulnerable (VU). The overall category was determined by the restricted Extent of Occurrence under Criterion B1.

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

Abbreviations: CO = Collapsed; VU = Vulnerable; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated.

Key findings and recommendations

Maldives-North was classified as Vulnerable because its EOO of 22,842 km^2 met the adopted Criterion B1 threshold when considered with continuing threats. Its AOO of 133 occupied 10-km grid cells was assessed as LC. The overall VU category therefore primarily reflects the geographic concentration of the northern atolls and their reef habitat, rather than direct evidence that most reefs are currently in a collapsed condition.

Criterion A1 was classified as Data Deficient (DD), with neither of the two available sites at or below the 5% hard-coral-cover threshold could not be established. The result remained DD across the 1–10% sensitivity range. A sample of two sites, neither of which could be included in the spatial-coverage calculation, is insufficient to characterise reef-area reduction across the ecoregion. As a result, the A1 classification is highly uncertain.

Observed thermal degradation under Criterion C1 was classified as VU. Severe bleaching occurred in 1998 and 2016, and moderate-to-severe bleaching was reported during the 2024 thermal event. The maximum annual DHW reached approximately 7.54°C-weeks in 1998, 8.49°C-weeks in 2016 and 9.15°C-weeks in 2024. These observations show that an VU result under the assessment model highlight the of damaging thermal events (Montefalcone et al., 2020a, 2026).

Criterion D1 was Data Deficient. Current observations were available for hard-coral cover and the algae–coral ratio, but suitable initial values could not be established. The available 1998 coral observations appeared already degraded and were therefore unsuitable as a reference condition. Parrotfish and grouper indicators were also DD because method-compatible baseline and current biomass estimates were unavailable. Data Deficient status must not be interpreted as indicating low risk.

Monitoring should be expanded across multiple northern atolls, depths and reef zones, with coordinates retained for every survey site. A consistent time series is needed to establish defensible initial conditions and quantify changes in hard-coral cover, community composition, recruitment, algae and structural complexity. Fish surveys should record abundance, body size and surveyed area so that parrotfish and grouper biomass can be estimated. Local actions should minimise dredging, reclamation, wastewater discharge, anchoring, marine debris and unsustainable fishing, particularly at reefs demonstrating strong recruitment or post-bleaching recovery.

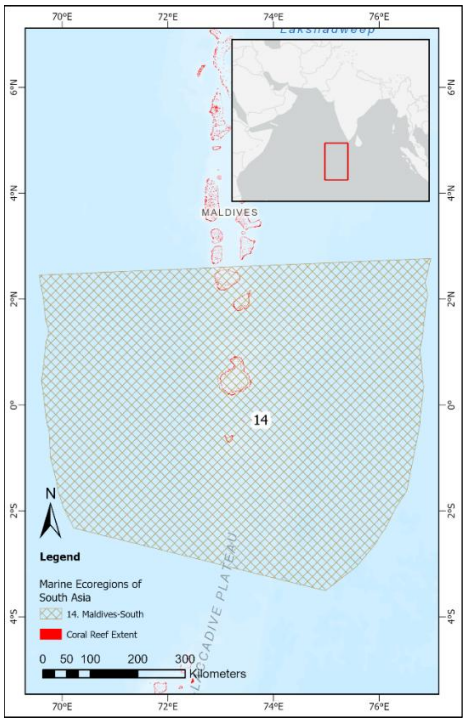
11.6. Maldives-South, Vulnerable (VU)

Spatial distribution

The Maldives-South coral reef ecoregion encompasses the southern and equatorial portion of the Maldivian archipelago. It extends southwards from the central atolls towards the southernmost atoll systems along the Laccadive–Maldives–Chagos ridge. The assessment boundary encloses the southern atolls and their associated lagoons, reef channels, submerged carbonate platforms and ocean-facing reef slopes.

The validated spatial layer contains approximately 837.8 km^2 of mapped coral reef habitat. Coral reefs are concentrated around shallow atoll platforms rather than being uniformly distributed throughout the wider marine polygon. Reef habitats include continuous and discontinuous atoll rims, lagoonal patch reefs, faros, pinnacles, channel-associated reefs and steep outer reef slopes. Deep waters separating the atolls contain little or no shallow coral reef habitat.

Compared with the central and northern Maldives, the southern atolls are generally more widely separated and exposed to equatorial and open-ocean conditions. Their distribution and isolation create a distinctive geographic setting while maintaining regional connectivity along the broader Laccadive–Maldives–Chagos ridge.



Ecosystem description

Maldives-South is an oceanic atoll ecosystem characterised by submerged carbonate platforms, extensive reef rims, lagoons, passes and steep ocean-facing slopes. The reefs develop in warm,

clear and generally oligotrophic waters with limited terrestrial sediment input. Their equatorial position and exposure to the open Indian Ocean distinguish them from the northern and central Maldivian assessment units.

Reef processes are strongly influenced by seasonal monsoon circulation, tidal exchange, oceanic currents, wave exposure and water movement through atoll channels. These processes connect outer reef slopes, channels, lagoons and patch reefs while producing substantial variation in current velocity, wave energy and habitat exposure.

Coral communities include major Indo-Pacific reef-building genera such as *Acropora*, *Porites*, *Pocillopora*, *Montipora*, *Pavona* and massive merulinid corals. Structurally complex reef habitats support diverse assemblages of reef fishes, sharks, rays, marine turtles, molluscs, crustaceans, echinoderms and other reef-associated organisms.

The ecoregion is assessed separately because of its equatorial location, stronger open-ocean influence, atoll spacing and distinctive thermal and hydrodynamic conditions. The principal threat is climate-induced coral bleaching. Additional pressures include fishing, tourism and coastal infrastructure, dredging and reclamation, wastewater pollution, marine debris, anchoring and other local reef disturbances.

Ecoregion characteristics

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
Maldives-South	Diverse Indo-Pacific reef-building corals, including *Acropora*, *Porites*, *Pocillopora* and *Montipora*; diverse reef fishes, sharks, rays, marine turtles, molluscs, crustaceans and echinoderms. Habitats include atoll rims, lagoonal patch reefs, faros, channels and steep outer reef slopes.	Southern and equatorial oceanic atolls on the Laccadive–Maldives–Chagos ridge; clear, warm and oligotrophic waters; limited natural terrestrial sediment input; strong open-ocean exposure, currents, wave energy, monsoon circulation and tidal exchange.	Climate-induced bleaching and ocean warming; fishing pressure; tourism development; dredging, reclamation and other coastal modification; wastewater and nutrient pollution; marine debris; anchoring; sea-level rise and ocean acidification.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
0.0% of 11 sites; none of the sites was at or below the 10% hard-coral-cover threshold	99 occupied 10-km grid cells	22,088 km^2	No primary C1 component exceeded LC. The 95th-percentile annual maximum DHW reached approximately 7.72°C-weeks in 1998 and 7.96°C-weeks in 2016.	Hard coral cover	43.95% ± 17.15 SD (n = 21)	28.37% ± 14.55 SD (n = 11)
				Algae–coral ratio	0.355 ± 0.156 SD (n = 121)	0.267 ± 0.257 SD (n = 104)
				Herbivore abundance	DD	DD
				Piscivore abundance	DD	DD

Eight of the 11 Criterion A sites were georeferenced, but they occurred in only four 10-km grid cells. The monitoring data therefore covered approximately 1.5% of EOO grid cells and 4.1% of

AOO grid cells. The Criterion A result should be interpreted in light of this limited spatial representation.

Criteria assessment

Overall, the risk of collapse of coral reefs in the Maldives-South ecoregion was assessed as Vulnerable (VU). The overall category was determined by the restricted Extent of Occurrence under Criterion B1.

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

Abbreviations: CO = Collapsed; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; NE = Not Evaluated.

Key findings and recommendations

Maldives-South was classified as Vulnerable because its EOO of 22,088 km^2 met the adopted Criterion B1 threshold when considered with continuing threats. Its AOO of 99 occupied 10-km grid cells was assessed as LC. The VU category reflects the geographic concentration of the southern reef systems rather than evidence that the ecoregion is currently collapsed.

Criterion A1 was classified as Least Concern, with none of the 11 monitored sites at or below the 5% hard-coral-cover threshold. The classification remained LC throughout the assessed 1–10% threshold-sensitivity range. However, the monitoring sites represented only a small proportion of the ecoregion's EOO and AOO, and localised reef loss may therefore be underrepresented.

Observed thermal degradation under Criterion C1 was assessed as Vulnerable. Severe and substantial bleaching and mortality occurred in 1998 and 2016. The 95th-percentile annual maximum DHW reached approximately 7.72°C-weeks in 1998 and 7.96°C-weeks in 2016, with

maximum values of 8.01 and 8.46°C-weeks**,** respectively. The 2016 event caused substantial reductions in coral cover and reef carbonate-production capacity. These observations support an operational severe-event threshold near 8°C-weeks while demonstrating that bleaching can begin below this level (Perry & Morgan, 2017a, 2017b).

Criterion D1 was assessed as Near Threatened, driven by hard-coral cover, which produced an NT result in 65.9% of uncertainty iterations. The algae–coral ratio was LC in 96.0% of iterations. This contrast suggests that reduced hard-coral cover has not consistently resulted in algae-dominated reef conditions. Parrotfish and grouper indicators remained DD because comparable current and baseline fish estimates were unavailable.

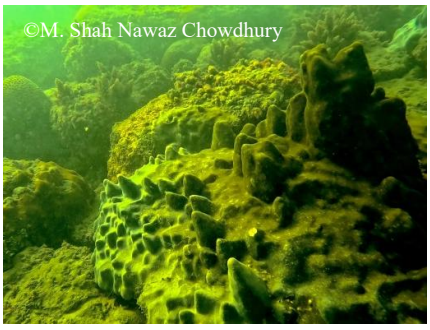
Monitoring should be expanded across southern atolls, reef zones and depths, with repeated surveys following major thermal events. Benthic monitoring should include coral cover, mortality, recruitment, community composition, algae and structural complexity. Fish surveys should record abundance, body size and surveyed area so that biomass-based parrotfish and grouper indicators can be evaluated. Local actions should minimise fishing pressure, dredging, reclamation, wastewater discharge, marine debris and anchoring, particularly at sites supporting coral recruitment, connectivity or rapid post-bleaching recovery.

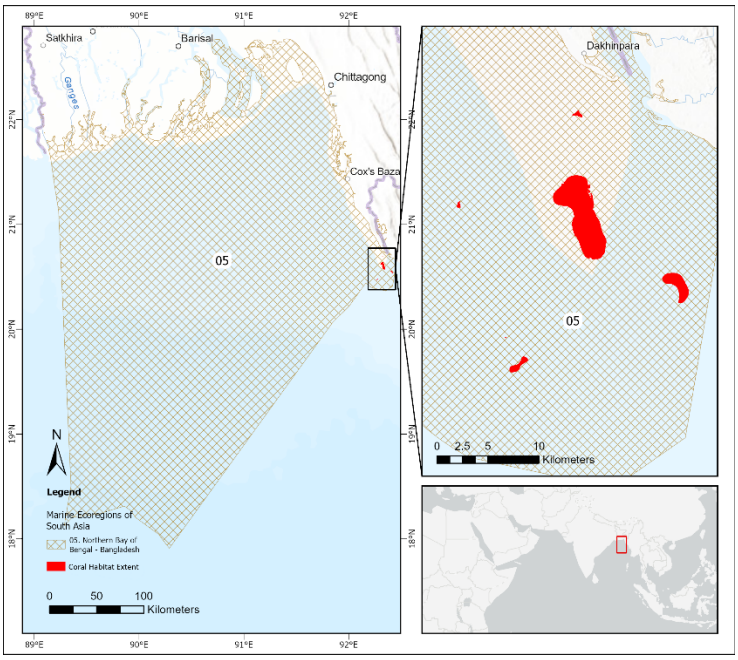
11.7. Northern Bay of Bengal - Bangladesh, Critically Endangered (CR)

Spatial distribution

The coral-associated benthic communities of Bangladesh are confined to St. Martin's Island and a series of adjacent sedimentary rocky habitats off the country's southeastern coast, approximately 9 km south of the Cox's Bazar–Teknaf peninsula (20°34′–20°39′ N; 92°18′–92°21′ E). The island's emergent landmass covers roughly 5–8 km^2, depending on tidal phase, and expands to about 12 km^2 when it includes the surrounding intertidal and shallow subtidal rocky platforms. Coral assemblages on St. Martin's Island occur exclusively on sedimentary rocky substrates, rather than on biogenic coral reef frameworks. These coral-colonized hard substrate habitats are distributed across intertidal rock pools, lagoonal margins, shallow subtidal zones, and offshore rocky platforms extending approximately 200–1500 m from the shoreline. Within this geomorphological context, coral assemblages occupy discrete patches of suitable hard substrate, forming a spatially discontinuous network of coral-bearing rocky habitats.

The St. Martin's Island coral community system does not constitute a true coral reef; rather, it comprises a clustered and fragmented assemblage of coral-colonized sedimentary rocky habitats distributed around the main island. The largest contiguous unit is the coastal rocky reef platform (17.85 km^2), complemented by smaller peripheral rocky reef patches to the north (0.30 km^2), west (0.17 km^2), southwest (1.02 km^2), and southeast (3.45 km^2), along with a minor shoal feature (0.02 km^2). The total extent of coral-bearing rocky substrate is approximately 22 km^2 situated within a broader extent of occurrence of approximately 325 km^2. This characterization aligns with the established scientific consensus that St. Martin's Island supports coral communities growing on sedimentary rocky platforms, and not on a biogenic carbonate framework; therefore, the rocky reef system should not be described as a coral reef ecosystem in the geological sense.







Maps of the Northern Bay of Bengal – Bangladesh Ecoregion, and examples of scleractinian corals within the shallow rocky habitats of Saint Martin's Island in the Northern Bay of Bengal–Bangladesh ecoregion.

Ecosystem description

This ecoregion represents a marginal coral-bearing coastal ecosystem developed under environmental conditions that differ markedly from the clear-water oceanic coral reef settings elsewhere in South Asia. Reef-building (Order Scleractinia) corals occur principally on sedimentary rocky substrate**s** in shallow waters subject to substantial seasonal environmental variability. The system is strongly influenced by monsoonal climate, freshwater discharge, sediment transport, and high turbidity characteristic of the northern Bay of Bengal and the wider Ganges–Brahmaputra–Meghna river system. These conditions are important in understanding the distinctive ecological setting of the island and the limited development of coral assemblages, all of which constrain carbonate reef accretion.

The ecoregion supports a diverse assemblage of hard and soft corals together with reef-associated fishes, algae, molluscs, crustaceans, and other benthic organisms. Recent assessments report 72 hard-coral species, five soft-coral species, and 84 reef-associated fish species. Common reef-building coral genera include *Porites*, *Favia*, *Pavona*, *Favites*, *Goniastrea*, *Platygyra*, *Goniopora*, and *Hydnophora*. These records demonstrate the presence of a diverse coral assemblage, but they should not by themselves be interpreted as evidence of a biogenic coral reef.

Its small spatial footprint, marginal environmental setting, and geographic isolation from other major coral-reef provinces provide a basis for treating St. Martin's Island as a distinct assessment unit, provided that the unit is defined according to its coral-bearing rocky habitat and associated biological assemblages, rather than being characterized simply as a coral reef. Major pressures include sedimentation, freshwater influence, pollution and other land- and marine-based sources of environmental degradation, coral and shell extraction, destructive fishing practices, tourism impacts, anchoring, shoreline modification, and increasing thermal stress.

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
Northern Bay of Bengal - Bangladesh	Hard and soft corals occurring on rocky habitats; reef-associated fishes, algae, molluscs, crustaceans and other benthic invertebrates; locally distinctive coral-algal communities.	Shallow continental-shelf setting influenced by monsoon rainfall, river discharge, seasonal salinity changes, high turbidity and sedimentation; limited hard substrate and no biogenic coral reef framework.	Sedimentation and freshwater discharge; pollution and declining water quality; coral and shell extraction; destructive fishing; anchoring; tourism pressure; coastal modification; ocean warming and bleaching.

Key values

Proportion of coral habitat lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
45.0% of 95 sites were at or below the 5% hard-coral-cover threshold	6 10-km grid cells	338 km^2	Acute clustering of annual maximum DHW ≥8 °C-weeks produced CR. In 2024, the 95th-percentile DHW reached 8.87 °C-weeks and the maximum reached 9.00 °C-weeks.	Hard coral cover	DD	10.35% ± 11.21 SD (n = 95)
				Algae-coral ratio	DD	0.836 ± 0.168 SD (n = 128)
				Herbivore abundance	DD	DD
				Piscivore abundance	DD	DD

All 95 Criterion A sites were georeferenced. They covered approximately 44.4% of EOO grid cells and 75.0% of AOO grid cells.

Criteria assessment

The risk of collapse of coral assemblages in the Northern Bay of Bengal, Bangladesh Ecoregion, is assessed as Critically Endangered (CR) under Criterion B1. This is consistent with the extremely restricted extent of coral-bearing rocky habitats and the long-term environmental degradation documented by earlier studies.

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	VU	NE	NE
B. Restricted Geographic Distribution	B1	B2	B3

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

Abbreviations: CO = Collapsed; 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 (CR) because its extent of occurrence (EOO) is only 338 km^2, satisfying the Criterion B1 threshold when considered in conjunction with ongoing anthropogenic and environmental threats. Its area of occupancy (AOO), represented by six occupied 10-km grid cells, met the Endangered (EN) threshold. This outcome reflects both the extremely restricted spatial distribution and the concentration of coral-associated habitats around a single island system composed of sedimentary rocky substrates, rather than a true biogenic reef framework.

Criterion A1 was assessed as Vulnerable: 45% of the 95 monitored sites exhibited ≤5% hard-coral cover. Sensitivity analyses produced outcomes ranging from Least Concern (LC) at a 1% threshold to Endangered (EN) at thresholds of 6–10%, indicating that the assessment is sensitive to the selected ecological benchmark. Nonetheless, the adopted 5% threshold yields a robust Vulnerable (VU) classification.

Criterion C1 was also Critically Endangered (CR) because of the pronounced spatial clustering of severe thermal-stress events. Locally paired observations linking thermal stress, coral bleaching, and subsequent mortality were not available for calibration. Consequently, the commonly applied regional threshold of 8-degree-heating-week (DHW) was transferred to this assessment area. The resulting classification should therefore be interpreted as an exposure-based assessment of thermal stress, rather than as evidence of a locally validated quantitative relationship between DHW and coral mortality.

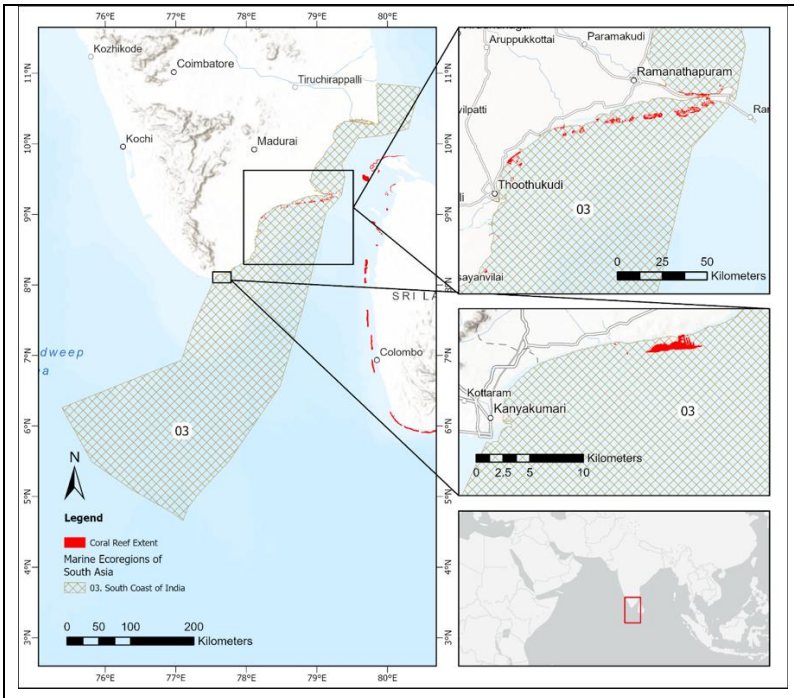
Criterion D1 was Data Deficient (DD). Contemporary observations of hard corals and coral-associated assemblages are available, but defensible historical baselines for assessing long-term changes are insufficient. Comparable historical data for fish community indicators are likewise Data Deficient (DD). Given the island's highly restricted distribution of suitable rocky habitat and the marginal environmental conditions for coral development, priority conservation actions should focus on protecting the remaining coral bearing rocky habitats (intertidal and subtidal) and their coral assemblages, reducing destructive extraction and fishing practices, minimizing tourism related physical disturbance and waste, controlling anchoring impacts, and improving sediment and wastewater management. Repeated, standardized benthic and fish surveys should be implemented to establish robust temporal baselines and to quantify changes in coral assemblage condition and associated fauna following thermal stress events.

11.8. South Coast of India, Endangered (EN)

Spatial distribution

The South Coast of India coral reef ecoregion occurs along the south-eastern coast of Tamil Nadu and includes the reef systems of Palk Bay, the Gulf of Mannar and adjoining southern coastal waters. In Palk Bay, coral habitat includes a narrow mainland fringing-reef tract near Rameswaram. In the Gulf of Mannar, reefs occur primarily around a chain of 21 islands extending approximately 140 km between Tuticorin and Rameswaram.

The assessment boundary follows the southern Indian continental shelf and separates these reefs from the West Coast of India, Lakshadweep and Sri Lankan assessment units. The validated spatial layer contains approximately 128.2 km^2 of mapped coral reef habitat, including fringing, patch, platform, pinnacle and shallow offshore reef formations.



Ecosystem description

This ecoregion combines the closely connected but environmentally contrasting reef systems of Palk Bay and the Gulf of Mannar. Palk Bay contains shallow, narrow and relatively turbid reefs influenced by restricted circulation, sedimentation and the north-east monsoon. The Gulf of Mannar supports a more extensive island-associated reef complex with reef flats, patch reefs, platform reefs and locally deeper reef habitats.

Coral communities include Acropora, Porites, Montipora, Favites and other massive and branching reef builders. Reef habitats occur in association with seagrass beds, macroalgae and soft-bottom habitats and support reef fishes, molluscs, echinoderms, sea cucumbers, turtles and dugongs.

The ecoregion has a long history of direct human use. Major pressures include fishing and extraction of reef organisms, historical coral mining, destructive gear, anchoring, sedimentation, sewage and industrial pollution, agricultural runoff, coastal development and repeated coral bleaching.

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
South Coast of India	Diverse branching and massive corals, including Acropora and Porites; reef fishes, seagrasses, macroalgae, molluscs, echinoderms, sea cucumbers, turtles and dugongs; strong ecological links among reef, seagrass and soft-bottom habitats.	Shallow continental-shelf reefs influenced by monsoon circulation, sedimentation and seasonal turbidity; narrow fringing reefs in Palk Bay and island-associated fringing, patch and platform reefs in the Gulf of Mannar.	Fishing and reef-organism extraction; historical coral mining; destructive gear and anchoring; sedimentation; sewage, industrial and agricultural pollution; coastal development; recurrent thermal bleaching.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
3.0% of 110 sites; approximately 3 of 110 sites were at or below the 10% hard-coral-cover threshold	23 10-km grid cells	6,050 km^2	Primary C1 component is VU. Severe bleaching occurred in 1998 and 2016; in 2016 the 95th-percentile DHW reached 9.35 °C-weeks and the maximum reached 10.56 °C-weeks.	Hard coral cover	40.17% ± 11.20 SD (n = 110)	22.18% ± 8.71 SD (n = 110)
				Algae-coral ratio	0.343 ± 0.142 SD (n = 110)	1.000 ± 0.000 SD (n = 60)
				Herbivore abundance (parrotfish density)	1,393.33 ± 278.76 ind./ha (one reference site)	908.38 ± 525.40 ind./ha (n = 24)
				Piscivore abundance (grouper density)	1,533.33 ± 522.56 ind./ha (one reference site)	736.05 ± 368.61 ind./ha (n = 24)

All 110 Criterion A sites were georeferenced. They covered approximately 18.3% of EOO grid cells and 77.8% of AOO grid cells.

Criteria assessment

Overall, the risk of collapse of coral reefs in the South Coast of India ecoregion was assessed as Endangered (EN). The overall category was determined by Criterion B1.

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

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

Key findings and recommendations

South Coast of India was classified as Endangered because its EOO of 6,050 km^2 met the Criterion B1 threshold when considered with continuing threats. Its AOO of 23 occupied 10-km grid cells was Vulnerable. The overall EN category is therefore driven by restricted distribution rather than Criterion A.

Criterion A1 was Least Concern, with approximately 3% of 110 sites at or below the 10% hard-coral threshold. The classification remained LC throughout the 1-10% sensitivity analysis. The relatively high AOO coverage improves confidence in the spatial representation of the available monitoring sites, although the monitoring network does not cover the entire EOO.

Criterion C1 was VU under the regional acute and chronic spatial rules despite documented bleaching and mortality. Extensive bleaching occurred in 1998 at lower reconstructed DHW, while the 2016 and 2024 events reached a 95th percentile DHW of 9.35 °C-weeks. These observations demonstrate that bleaching can begin below the operational 8-DHW severe-event threshold (Arthur, 2000; Patterson Edward et al., 2018).

Criterion D1 was Vulnerable. Hard-coral cover and grouper density were VU, while the algae-coral ratio and parrotfish density were NT. Monitoring should continue across both Palk Bay and the Gulf of Mannar, with consistent benthic and fish methods. Management priorities include

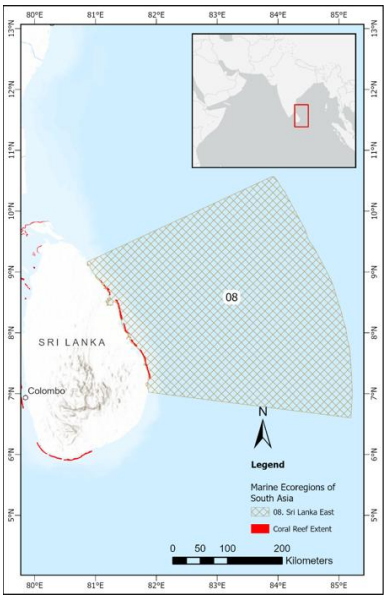
reducing destructive fishing and extraction, maintaining no-take protection where applicable, improving sewage and runoff control, preventing anchoring damage and supporting recovery following bleaching.

11.9. Sri Lanka East, Endangered (EN)

Spatial distribution

The Sri Lanka East coral reef ecoregion extends along the eastern Sri Lankan shelf and adjoining offshore waters. Coral reefs are concentrated around Trincomalee, Nilaveli, Pigeon Island, Batticaloa, Passikudah, Kalkudah and other suitable rocky and shallow coastal habitats.

The regional boundary separates the eastern reef systems from the northern and southern Sri Lankan assessment units. The validated spatial layer contains approximately 367.0 km^2 of mapped coral reef habitat. Reefs occur principally as shallow fringing reefs, patch reefs and coral communities established on rocky and boulder substrates.





Map of Sri Lanka East Ecoregion and coral reef occurred in Kayankerni Marine Sanctuary

Ecosystem description

Sri Lanka East contains some of the country's most extensive fringing-reef habitats. Reef development is influenced by north-east monsoon exposure, seasonal currents, freshwater input, turbidity and sedimentation. Conditions vary among protected bays, nearshore rocky reefs and more exposed offshore habitats.

The ecoregion supports diverse hard-coral assemblages, reef fishes and benthic invertebrates. Live coral, dead coral, algae, seagrass, sand, rubble and rocky substrate form a heterogeneous habitat mosaic. Pigeon Island and other eastern reef complexes are particularly important for coral and reef-fish diversity.

The combination of eastern monsoon exposure, nearshore fringing-reef geomorphology and distinct seasonal oceanography supports treatment as a separate assessment unit. Threats

include thermal bleaching, fishing, anchoring, tourism, pollution, sedimentation, coastal development and plastic contamination.

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
Sri Lanka East	Diverse reef-building corals, reef fishes and benthic invertebrates; heterogeneous mosaics of live coral, dead coral, algae, seagrass, sand and rubble; important coral and fish assemblages at Pigeon Island and other eastern reefs.	Shallow eastern fringing and rocky reefs influenced by the north-east monsoon, seasonal currents, freshwater input, turbidity and wave exposure; locally clearer water than heavily sedimented western sectors.	Thermal bleaching; fishing and anchoring; tourism; sedimentation and declining water quality; coastal development; sewage and other pollution; plastics and microplastics.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
0.0% of 16 sites; none of the sites was at or below the 10% hard-coral-cover threshold	24 10-km grid cells	2,072 km^2	No primary C1 component exceeded LC. In 2016, the 95th-percentile DHW reached 5.27 °C-weeks and the maximum reached 5.32 °C-weeks.	Hard coral cover	48.90% ± 16.66 SD (n = 66)	37.87% ± 12.44 SD (n = 16)
				Algae-coral ratio	0.355 ± 0.156 SD (n = 121)	0.135 ± 0.225 SD (n = 34)
				Herbivore abundance	DD	DD
				Piscivore abundance	DD	DD

All 16 Criterion A sites were georeferenced. They covered approximately 11.8% of EOO grid cells and 22.2% of AOO grid cells.

Criteria assessment

Overall, the risk of collapse of coral reefs in the Sri Lanka East ecoregion was assessed as Endangered (EN). The overall category was determined by Criterion B1.

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

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
	LC	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Sri Lanka East was classified as Endangered because its EOO of 2,072 km^2 met the Criterion B1 threshold when considered with continuing threats. Its AOO of 24 occupied 10-km grid cells was Vulnerable. The overall category therefore reflects restricted distribution rather than a threatened result under Criteria A, C1 or D1.

Criterion A1 was Least Concern, with none of the 16 monitored sites at or below the 10% hard-coral threshold. The result remained LC across the 1-10% sensitivity range. Spatial coverage was greater than in several oceanic ecoregions but remained incomplete, particularly across the full EOO.

Criterion C1 was LC. Available literature documents thermal exposure and changes in reef condition but did not provide sufficiently matched DHW and mortality observations for independent local threshold calibration. The regional 8-DHW threshold was therefore applied, and the result should be interpreted cautiously (Thilakarathne et al., 2023b, 2024).

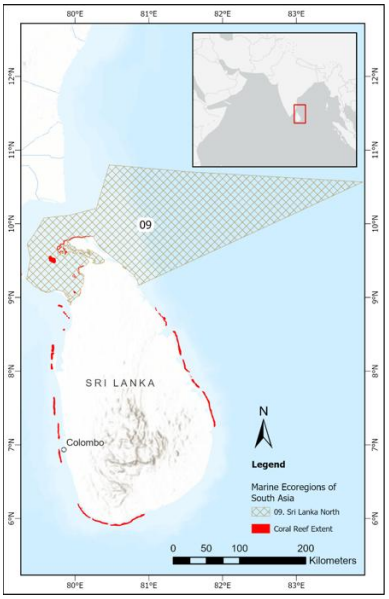
Criterion D1 was LC, with both hard-coral cover and the algae-coral ratio producing modal LC outcomes. Parrotfish and grouper indicators remained DD. Priorities are to maintain repeated monitoring across representative reef zones, add standardised fish biomass surveys, manage fishing and anchoring, improve wastewater and sediment control, and minimise unmanaged tourism impacts at heavily visited reefs.

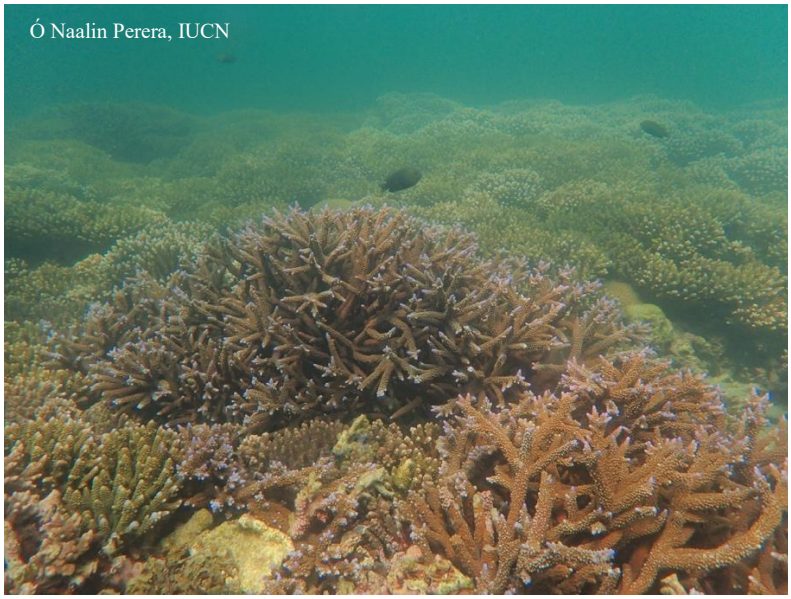
11.10. Sri Lanka North, Endangered (EN)

Spatial distribution

The Sri Lanka North coral reef ecoregion covers the northern Sri Lankan shelf, including reef habitats associated with the Jaffna Peninsula, Palk Strait, Palk Bay and adjoining northern waters. Coral habitat occurs as shallow fringing reefs, patch reefs, rocky shoals and coral communities established on hard substrate.

The assessment boundary separates the northern shallow-shelf system from the eastern, southern and western Sri Lankan units. The validated spatial layer contains approximately 178.5 km^2 of mapped coral reef habitat. The reefs are discontinuously distributed in shallow and often semi-enclosed waters with strong environmental variability.





Map of Sri Lanka North Ecoregion and coral reef recorded in Eumaithive Reef

Ecosystem description

Sri Lanka North is characterised by shallow reef habitats influenced by monsoon circulation, restricted water exchange, seasonal freshwater input, turbidity and exchange with the southern Indian shelf. These conditions distinguish the ecoregion from the more exposed ocean-facing reefs of eastern and southern Sri Lanka.

The ecoregion supports reef-building corals, reef fishes and benthic invertebrates associated with fringing reefs, patch reefs, sandstone or rocky shoals and shallow soft-sediment habitats. Environmental conditions can vary considerably among the Jaffna, Palk Bay and open northern shelf sectors.

The ecoregion is assessed separately because of its shallow semi-enclosed setting, proximity to the Indian continental shelf and distinctive monsoon, salinity and turbidity regime. Threats include thermal bleaching, intensive and destructive fishing, coral and other reef-resource extraction, anchoring, sedimentation, pollution and coastal development.

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
Sri Lanka North	Reef-building corals, reef fishes and benthic invertebrates occurring on shallow fringing reefs, patch reefs and rocky or sandstone shoals; habitat links with adjacent seagrass and soft-bottom systems.	Shallow northern shelf influenced by Palk Bay and Palk Strait, monsoon circulation, restricted exchange, seasonal turbidity and freshwater inputs; environmental connection with the southern Indian shelf.	Thermal bleaching; intensive and destructive fishing; reef-resource extraction; anchoring; sedimentation and turbidity; sewage and other pollution; unplanned coastal development.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
0.0% of 1 site; the single monitored site was above the 10% hard-coral-cover threshold	20 10-km grid cells	3,208 km^2	Acute clustering of annual maximum DHW ≥8 °C-weeks produced EN. The 95th-percentile DHW reached 9.60 °C-weeks in 2016 and 9.48 °C-weeks in 2024.	Hard coral cover	DD	11.45% (n = 1)
				Algae-coral ratio	DD	0.667 ± 0.330 SD (n = 11)
				Herbivore abundance	DD	DD
				Piscivore abundance	DD	DD

The single Criterion A site was georeferenced and covered approximately 2.0% of EOO grid cells and 4.5% of AOO grid cells.

Criteria assessment

Overall, the risk of collapse of coral reefs in the Sri Lanka North ecoregion was assessed as Endangered (EN). The overall category was determined by Criteria B1 and C1.

CRITERION			
A. Reduction in Geographic Distribution	**A1**	**A2**	**A3**
	Past 50 years	Future or any 50y period	Historical (1750)
	DD	**NE**	**NE**
B. Restricted Geographic 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 (1970)	Future or any 50y period	Historical (1750)
	VU	**CR**	**NE**
D. Disruption of biotic processes	**D1**	**D2**	**D3**
	Past 50 years (1970)	Future or Any 50y period	Historical (1750)
	DD	**NE**	**NE**
E. Quantitative Risk analysis	**NE**		

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	DD	NE	NE
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Sri Lanka North was classified as Endangered, jointly supported by Criterion B1 and B2. Its EOO of 3,208 km^2 was EN, while its AOO of 20 occupied 10-km grid cells was EN. Acute clustering of severe thermal exposure also produced an VU result.

Criterion A1 was DD because the estimate was based on only one monitored site. Although the site was above the 10% hard-coral threshold, it covered only 2.0% of EOO grid cells and 4.5% of AOO grid cells. The result is therefore highly uncertain and cannot demonstrate that geographic reduction has been limited throughout the ecoregion. Therefore, it is assessed as DD.

Criterion C1 was VU. The maximum DHW reached 9.90 °C-weeks in 2016 and 10.03 °C-weeks in 2024. Ecoregion-wide mortality measurements were unavailable for these events, so the regional threshold was applied rather than independently calibrated (Arulananthan et al., 2021; Thilakarathne et al., 2023b).

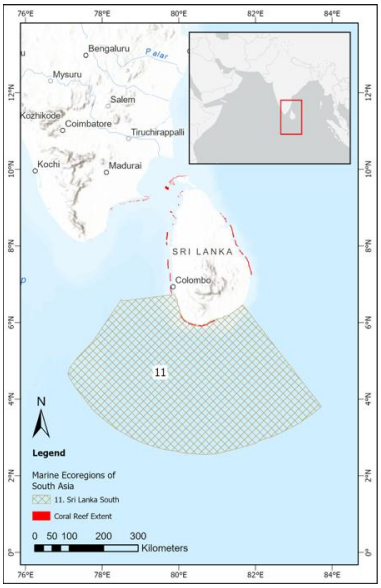
Criterion D1 was DD because historical baselines could not be established for hard-coral cover or the algae-coral ratio, and fish indicators were not assessable. Monitoring should be expanded across the Jaffna Peninsula, Palk Bay and northern shelf, with repeated georeferenced benthic and fish surveys. Management should address destructive fishing, extraction, anchoring, sedimentation, wastewater and other coastal pressures.

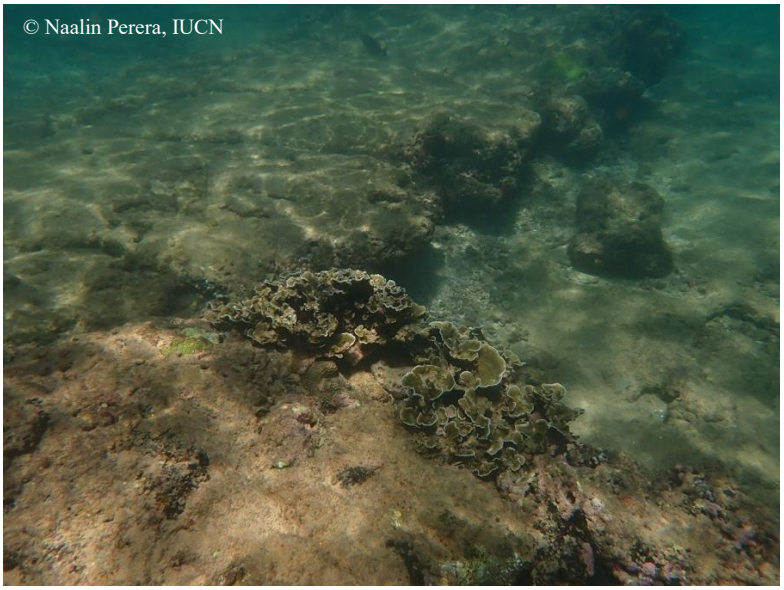
11.11. Sri Lanka South, Critically Endangered (CR)

Spatial distribution

The Sri Lanka South coral reef ecoregion extends along the southern coast of Sri Lanka and its adjoining shallow shelf and offshore reef habitats. Coral communities occur as fringing reefs, patch reefs, rocky reefs and small offshore reef formations associated with suitable hard substrate.

The assessment boundary separates the exposed southern coast from the eastern and western Sri Lankan assessment units. The validated spatial layer contains approximately 243.2 km^2 of mapped coral reef habitat. Reef patches are distributed discontinuously along the coast and are exposed to open-ocean waves, currents and seasonal monsoon conditions.





Map of Sri Lanka South Ecoregion and coral reef recorded in Hikkaduwa National Park

Ecosystem description

Sri Lanka South is distinguished by comparatively exposed open-ocean conditions, strong wave energy and seasonal monsoon forcing. Reefs occur on a narrow continental shelf and include shallow fringing and rocky reef communities as well as small offshore patches. Water clarity and sediment influence vary locally with coastal runoff, bays and exposure.

The ecoregion supports reef-building corals, reef fishes and benthic invertebrates adapted to exposed southern-coast conditions. Coral, algae, rubble, rock, sand and associated coastal habitats form a spatially variable mosaic.

Treatment as a separate assessment unit reflects its southern geographic position, open-ocean exposure and different hydrodynamic setting relative to eastern, northern and western Sri Lanka.

Threats include thermal bleaching, tourism, coastal infrastructure, pollution, fishing, anchoring, sedimentation and storm-related disturbance.

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
Sri Lanka South	Reef-building corals, reef fishes and benthic invertebrates associated with exposed fringing, rocky and offshore patch reefs; mosaics of coral, algae, rubble, rock and sand.	Open-ocean southern shelf with strong wave exposure, currents and seasonal monsoon forcing; locally clear offshore waters but variable nearshore turbidity and sediment influence.	Thermal bleaching; tourism and coastal infrastructure; wastewater and other pollution; fishing and anchoring; sedimentation and runoff; storm and wave disturbance.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
0.0% of 2 sites; neither site was at or below the 10% hard-coral-cover threshold	12 10-km grid cells	1,898 km^2	Acute clustering of annual maximum DHW ≥8 °C-weeks produced EN. In 2016, the 95th-percentile DHW reached 10.53 °C-weeks and the maximum reached 10.66 °C-weeks.	Hard coral cover	DD	17.81% ± 3.10 SD (n = 2)
				Algae-coral ratio	DD	0.570 ± 0.080 SD (n = 4)
				Herbivore abundance	DD	DD
				Piscivore abundance	DD	DD

Both Criterion A sites were georeferenced. They covered approximately 6.2% of EOO grid cells and 12.5% of AOO grid cells.

Criteria assessment

Overall, the risk of collapse of coral reefs in the Sri Lanka South ecoregion was assessed as Critically Endangered (CR). The overall category was determined by Criterion B1.

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	DD	NE	NE
B. Restricted Geographic 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 (1970)	Future or any 50y period	Historical (1750)
	VU	CR	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1970)	Future or Any 50y period	Historical (1750)
	DD	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Sri Lanka South was classified as Critically Endangered because its EOO of 1,898 km^2 met the Criterion B1 threshold when considered with continuing threats. Its AOO of 12 occupied 10-km grid cells was EN. The overall CR category is therefore driven by the ecoregion's highly restricted distribution.

Criterion A1 was DD, neither of the two monitored sites at or below the 5% hard-coral threshold could not represent the whole ecoregion. The classification remained DD across the 1-10% sensitivity range. However, two sites cannot adequately represent the environmental and ecological variation across the southern coastline, and the A1 result remained highly uncertain and assessed as DD.

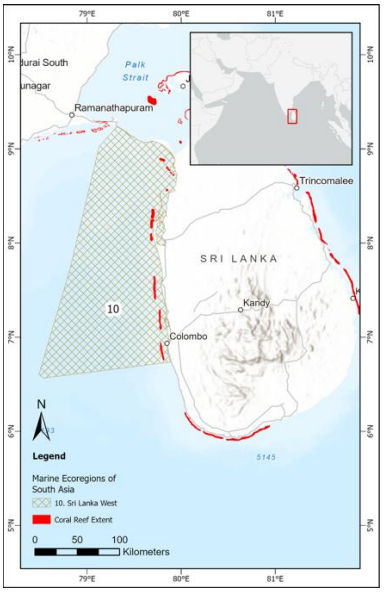
Criterion C1 was VU because of acute clustering of severe thermal exposure. Extensive mortality was reported during the 1998 bleaching event even though reconstructed DHW was relatively low, while maximum DHW reached 10.66 °C-weeks in 2016. The mismatch between historical observations and gridded exposure prevented local calibration, so the regional threshold was retained (Arulananthan et al., 2021; Thilakarathne et al., 2023b).

Criterion D1 was DD because suitable initial values were unavailable for hard-coral cover and the algae-coral ratio, and fish indicators were not assessable. Monitoring should be expanded across exposed and sheltered southern reefs and should include community composition, recruitment, structural complexity and fish biomass. Management should minimise tourism damage, anchoring, coastal pollution, sediment runoff and unsustainable fishing.

11.12. Sri Lanka West, Endangered (EN)

Spatial distribution

The Sri Lanka West coral reef ecoregion extends along the western and south-western Sri Lankan shelf between the northern and southern assessment units. Reef habitat occurs as fringing reefs, patch reefs, rocky reefs and offshore reef complexes distributed discontinuously along the coast. The validated assessment boundary contains approximately 323.5 km^2 of mapped coral reef habitat. Reef development is concentrated where hard substrate and suitable water conditions occur, while broad areas of the shelf contain sand, mud or other non-reef habitat. The ecoregion is exposed to densely populated coastal areas and major centres of tourism, fishing and coastal infrastructure.





Map of Sri Lanka West Ecoregion and its coral reef recorded in Thalawila Reef

Ecosystem description

Sri Lanka West is characterised by coastal reefs exposed to the south-west monsoon, seasonal wave energy, runoff, turbidity and strong coastal currents. Environmental conditions vary among sheltered nearshore reefs, rocky habitats and more exposed offshore reef patches. Seasonal sediment and freshwater inputs can strongly influence water clarity and coral condition.

The ecoregion supports reef-building corals, reef fishes and benthic invertebrates associated with coral, algae, rock, rubble, sand and other coastal habitats. Its reef communities occur close to densely populated and heavily used coastal areas, distinguishing the pressure regime from less developed sectors of the region.

The ecoregion is assessed separately because of its western monsoon exposure, coastal-current regime, geomorphology and concentration of human activities. Major threats include bleaching,

fishing, tourism, sedimentation, sewage and industrial pollution, harbour and coastal development, dredging, reclamation, anchoring and marine debris.

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
Sri Lanka West	Reef-building corals, reef fishes and benthic invertebrates associated with fringing, rocky, patch and offshore reefs; mosaics of coral, algae, rock, rubble and sand.	Western shelf exposed to the south-west monsoon, seasonal wave energy, coastal currents, freshwater runoff, turbidity and sedimentation; reef habitat located close to densely populated coastal areas.	Thermal bleaching; intensive fishing; tourism; sewage, industrial and plastic pollution; sedimentation and runoff; harbour and coastal development; dredging, reclamation and anchoring.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
42.0% of 12 sites; 5 of 12 sites were at or below the 10% hard-coral-cover threshold	20 10-km grid cells	4,173 km^2	Acute clustering of annual maximum DHW ≥8 °C-weeks produced VU. The 95th-percentile DHW reached 10.28 °C-weeks in 2016 and 9.22 °C-weeks in 2024.	Hard coral cover	40.17% ± 11.20 SD (n = 110; South Coast of India proxy)	12.75% ± 11.80 SD (n = 12)
				Algae-coral ratio	0.343 ± 0.142 SD (n = 110; South Coast of India proxy)	0.547 ± 0.345 SD (n = 39)
				Herbivore abundance	DD	DD
				Piscivore abundance	DD	DD

All 12 Criterion A sites were georeferenced. They covered approximately 5.6% of EOO grid cells and 12.5% of AOO grid cells.

Criteria assessment

Overall, the risk of collapse of coral reefs in the Sri Lanka West ecoregion was assessed as Endangered (EN). The overall category was determined by Criteria B1, C1 and D1.

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	NT	NE	NE
B. Restricted Geographic 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 (1970)	Future or any 50y period	Historical (1750)
	VU	CR	NE

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	NT	NE	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1970)	Future or Any 50y period	Historical (1750)
	EN	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Sri Lanka West was classified as Endangered, with convergent EN outcomes under Criteria B and D1. Its EOO of 4,173 km^2 was EN and its AOO of 20 occupied 10-km grid cells was EN. The overall result is therefore supported by restricted distribution, severe thermal exposure and biotic degradation.

Criterion A1 was NT: five of 12 monitored sites were at or below the 5% hard-coral threshold. Sensitivity results changed from NT at thresholds of 1-5% to VU at thresholds of 6-10%, showing that the classification depends on the adopted ecological threshold. Spatial monitoring coverage remained limited.

Criterion C1 was VU. Severe bleaching and mortality were documented in 1998 when reconstructed DHW was lower, while the 2016 and 2024 events reached maxima of 10.80 and 9.64 °C-weeks. The regional 8-DHW threshold was applied with explicit uncertainty because directly matched ecoregion-wide mortality estimates were unavailable (Arulananthan et al., 2021; Thilakarathne et al., 2023b).

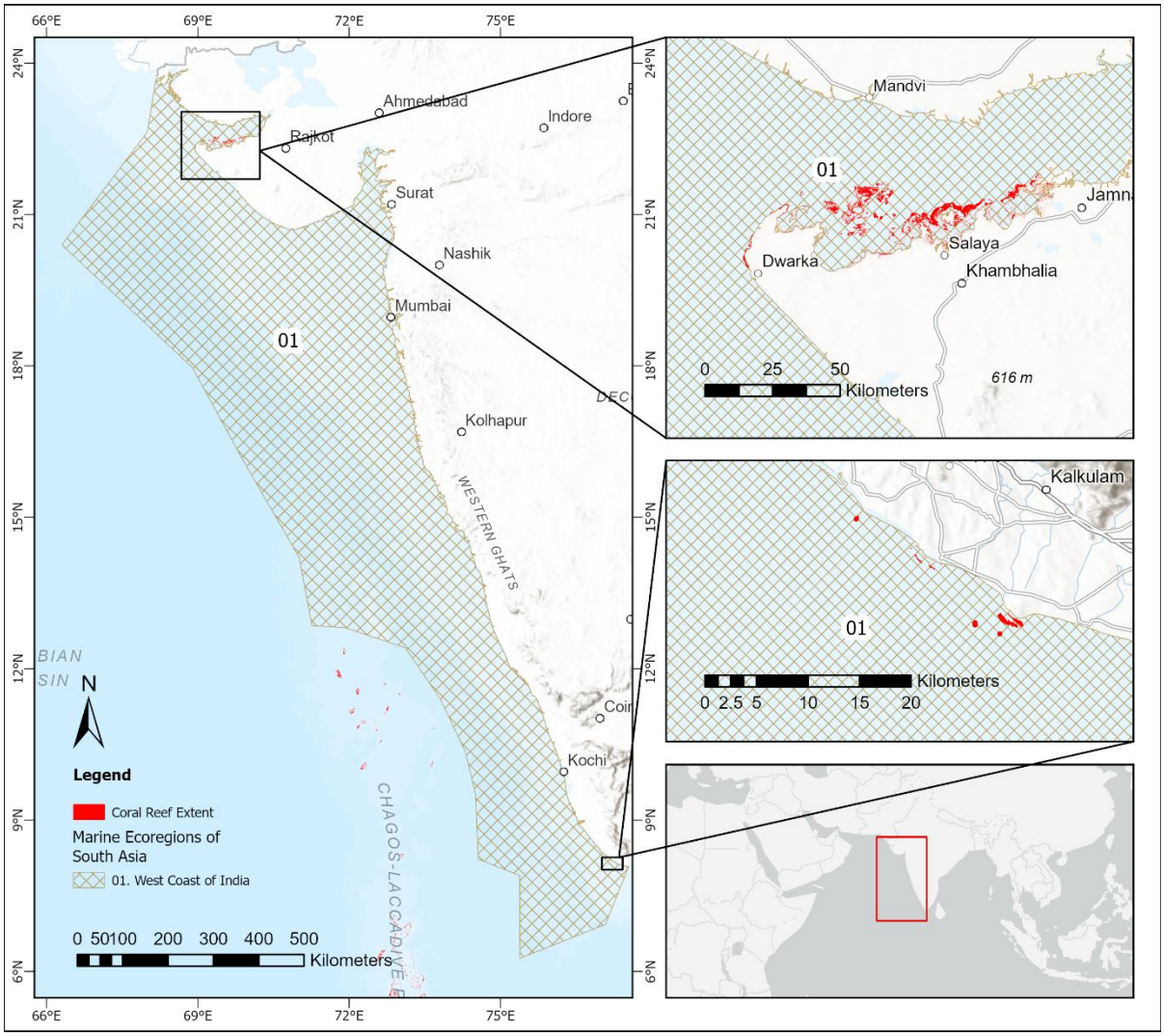
Criterion D1 was EN, driven by hard-coral cover, which produced an EN outcome in 98.5% of uncertainty iterations. The algae-coral ratio was NT in 72.1% of iterations; fish indicators were DD. The use of South Coast of India proxy baselines adds uncertainty. Priorities include expanded long-term monitoring, development of local baselines, standardised fish biomass surveys and stronger control of wastewater, sediment, coastal construction, fishing, anchoring and tourism impacts.

11.13. West Coast of India, Vulnerable (VU)

Spatial distribution

The West Coast of India coral reef ecoregion follows the Arabian Sea margin of mainland India from Gujarat southwards along the western continental shelf. Coral reefs are concentrated principally in the Gulf of Kachchh, with smaller and more discontinuous coral communities and patch reefs occurring along suitable sectors of the mainland coast.

The assessment boundary excludes the offshore oceanic atolls of Lakshadweep. The validated spatial layer contains approximately 202.5 km^2 of mapped coral reef habitat. Reef habitat is discontinuous and occurs mainly as shallow patch, platform, fringing and island-associated reefs surrounded by extensive non-reef shelf environments.





Coral Reef recorded at Gulf of Kachchh, Mithapur reef
©Chandran Rethinaraj

Ecosystem description

West Coast of India reefs are distinguished from the clear-water atolls of Lakshadweep by their continental-shelf setting and exposure to monsoon circulation, river discharge, sedimentation and high turbidity. The Gulf of Kachchh reefs persist under particularly variable conditions, including strong tidal currents, broad intertidal areas and seasonal changes in salinity and temperature.

Coral communities include massive and stress-tolerant genera such as Favia, Favites, Porites, Goniopora, Goniastrea and Turbinaria, together with reef fishes, algae, sponges, molluscs, crustaceans and other benthic fauna. Reef habitats occur alongside mangroves, creeks, mudflats, rocky shores and soft-sediment systems.

The ecoregion is assessed separately because of its turbid continental setting, discontinuous reef distribution and environmentally tolerant coral assemblages. Major pressures include coastal and industrial development, ports and shipping, dredging, sedimentation, pollution, fishing, extraction and thermal bleaching.

Ecoregion	Key Biotic Components	Key Abiotic Components	Key Threats
West Coast of India	Stress-tolerant coral assemblages including *Favia, Favites, Porites, Goniopora, Goniastrea* and *Turbinaria*; reef fishes, algae, sponges, molluscs, crustaceans and other benthic fauna; close association with mangroves and intertidal habitats.	Shallow continental shelf influenced by strong monsoon circulation, river runoff, sedimentation, turbidity, tidal currents and seasonal salinity and temperature variability; discontinuous patch and platform reefs.	Coastal and industrial development; port construction, shipping and dredging; sedimentation and pollution; fishing and extraction; anchoring; ocean warming and coral bleaching.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		SST-anomaly past 50 years (Criterion C)	Biotic Indicator Values (Criterion D)		
	AOO	EOO		Indicator	Baseline	Current
0.0% of 3 sites; none of the sites was at or below the 10% hard-coral-cover threshold	33 occupied 10-km grid cells	117,673 km^2	Acute clustering of annual maximum DHW ≥8 °C-weeks produced VU. The 95th-percentile DHW reached 8.03 °C-weeks in 2010, 8.58 in 2016, 11.24 in 2020 and 12.24 in 2024.	Hard coral cover	DD	15.93% ± 4.99 SD (n = 3)
				Algae-coral ratio	DD	0.392 ± 0.261 SD (n = 20)
				Herbivore abundance	DD	DD
				Piscivore abundance	DD	DD

All three Criterion A sites were georeferenced, but they covered approximately 0.1% of EOO grid cells and 0.0% of the AOO grid cells used in the coverage overlay.

Criteria assessment

Overall, the risk of collapse of coral reefs in the West Coast of India ecoregion was assessed as Vulnerable (VU). The overall category was determined by Criteria B2 and C1.

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	DD	NE	NE
B. Restricted Geographic 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 (1970)	Future or any 50y period	Historical (1750)
	VU	CR	NE
D. Disruption of biotic processes	D1	D2	D3
	Past 50 years (1970)	Future or Any 50y period	Historical (1750)
	DD	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

West Coast of India was classified as Vulnerable, jointly supported by Criterion B2 and Criterion C1. Although its EOO is extensive at 117,673 km^2 and was normalised to LC in the final synthesis, reef habitat is discontinuous and its AOO of 33 occupied 10-km grid cells was VU.

Criterion A1 was DD, with none of the three monitored sites at or below the 5% hard-coral threshold. However, the three sites represented approximately 0.1% of EOO cells and did not overlap the AOO cells in the coverage calculation, so the result is highly uncertain at ecoregion scale, and it remained as DD.

Criterion C1 was VU because of acute clustering of severe thermal exposure. The 2010 and 2016 events exceeded approximately 8 DHW, while very high localised exposure was recorded in 2020 and 2024. Limited mortality documented in some high-exposure areas illustrates that DHW is an exposure indicator rather than a deterministic predictor of ecological response (Arthur, 2000; Thinesh et al., 2025).

Criterion D1 was DD because adequate historical baselines were unavailable for hard-coral cover and the algae-coral ratio, while fish indicators could not be assessed. Monitoring should be expanded beyond the currently represented sites and should cover the geographic and environmental range of the ecoregion. Management priorities include controlling dredging, port and industrial impacts, sedimentation, pollution, destructive fishing and anchoring while maintaining mangrove-reef and coastal-habitat connect.