REGIONAL REPORT V.0

Red List of Ecosystems assessment of East Asian coral reefs

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ABSTRACT

East Asian coral reefs extend from **13.9°S to 31.0°N** across **16 countries and territories,** covering an estimated **75,765 km² of shallow coral reef habitat**, representing **30.3%** of the global coral reef extent and encompassing **25** coral reef ecoregions. Of this, 35,620 km² of mapped coral reef was assessed in this study.

The region hosts **the worldwide highest diversity of corals, invertebrates and fish, notably in the Coral Triangle, as well as the highest area of coral reefs** and is characterized by **an**

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KEYWORDS

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

extraordinary level of endemism. These ecosystems face increasing pressure from **unsustainable fishing practices, coastal development, maritime pollution, rising sea levels and climate change**. The IUCN Red List of Ecosystems assessment, drawing on reef monitoring data **from 1983 to 2025 compiled through the GCRMN East Asia network, combined with data obtained from the MERMAID data portal and the Reef Life Survey dataset**, found that coral reefs within **all of the 25** ecoregions assessed are at a high risk of collapse and are **classified as Critically Endangered across all criteria**. This overall result was primarily driven by **future ocean warming projections**. Based on historical declines and present conditions alone, **22 ecoregions are assessed as threatened,** with five of them considered Critically Endangered. This was mainly due to recurrent heat stress as well as depleted parrotfish and grouper populations. These results emphasize the urgent need for **climate mitigation and the promotion of sustainable fishing practices** to safeguard the region's coral reefs.

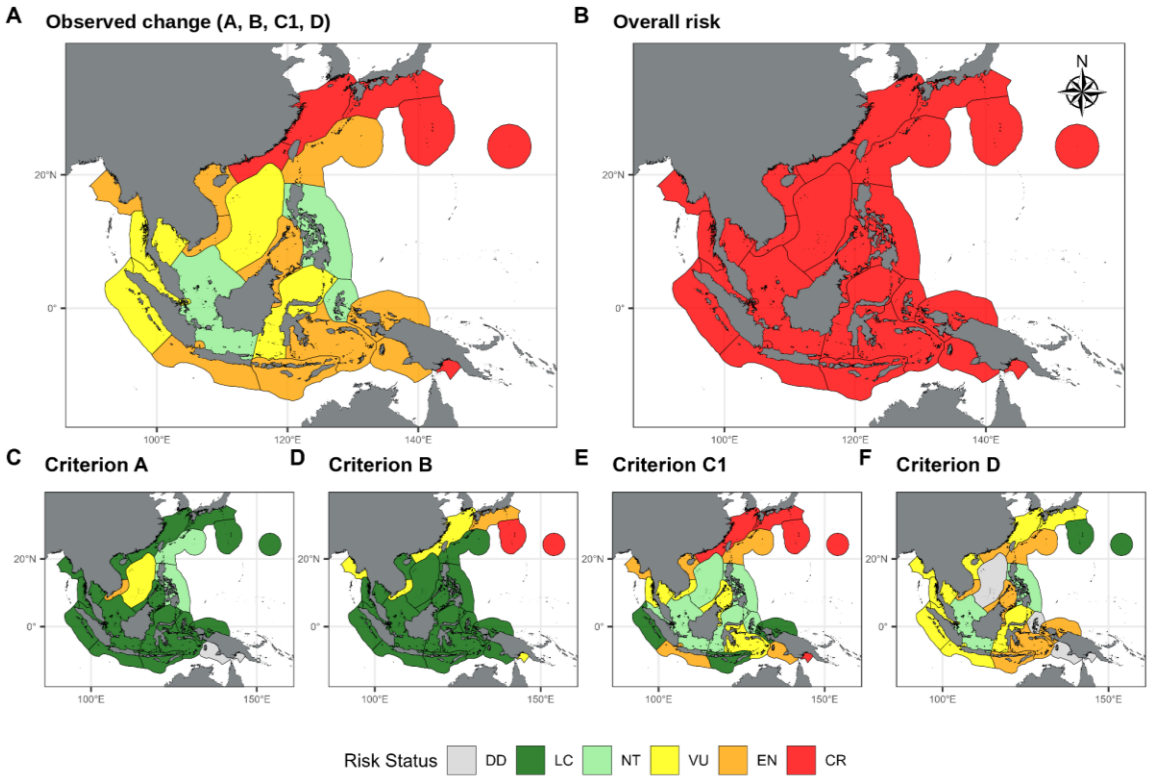


Figure 1 | Risk status of coral reef ecosystems in 25 East Asian marine ecoregions under the IUCN Red List of Ecosystems. A depicts the risk status arising from observed changes, taken as the highest risk

status returned by criteria A, B, C1 and D. B shows the overall Red List of Ecosystems risk status, which includes projected ocean warming assessed under sub-criterion C2 based on forecasted thermal stress over the next 50 years (2026–2075). C–F show the risk status under criteria A, B, C1 and D. Ecoregions marked as DD are Data Deficient for a given criterion.

Study Area

This Red List of Ecosystems (RLE) assessment evaluates the risk of collapse for coral reefs across the East Asian region as of 2026. **East Asian coral reefs** (IUCN Global Ecosystem Typology M1.3 - photic coral reefs) extend from **13.9°S to 31.0°N** across **16 countries and territories** (Brunei Darussalam, Cambodia, China, Hong Kong, Indonesia, Japan, Macao, Malaysia, Myanmar, Papua New Guinea, Philippines, Singapore, Taiwan, Thailand, Timor-Leste, Vietnam), covering an estimated **75,765 km^2 of shallow coral reef habitat** (Kimura et al., 2026b), and representing **30.3%** of the global coral reef extent. Of this, 35,620 km^2 of mapped coral reef was assessed in this study, calculated from the regionally verified version of the UNEP-WCMC Millennium Coral Reef layer.

Coral reefs of the **East Asian region** were grouped into **25** ecoregions drawing on the Marine Ecoregions of the World (MEOW) framework developed by Spalding et al., (2007). **Boundaries of ecoregions were refined using inputs from local experts who were engaged in a series of regional workshops and provided inputs in an attempt to verify reef** extent between adjacent ecoregions. These coral reef ecoregions capture ecological variation along gradients in terms of **coral and reef fish biodiversity, environmental conditions, structural complexity, productivity, as well as their exposure to threats (i.e., coral bleaching, overfishing, land reclamation, pollution)**, and are equivalent to Level 4 of the IUCN Global Ecosystem Typology (regional sub-groups). Coral reefs in each ecoregion were independently assessed using the IUCN Red List of Ecosystems criteria (details on data collection & monitoring in Annex 1).

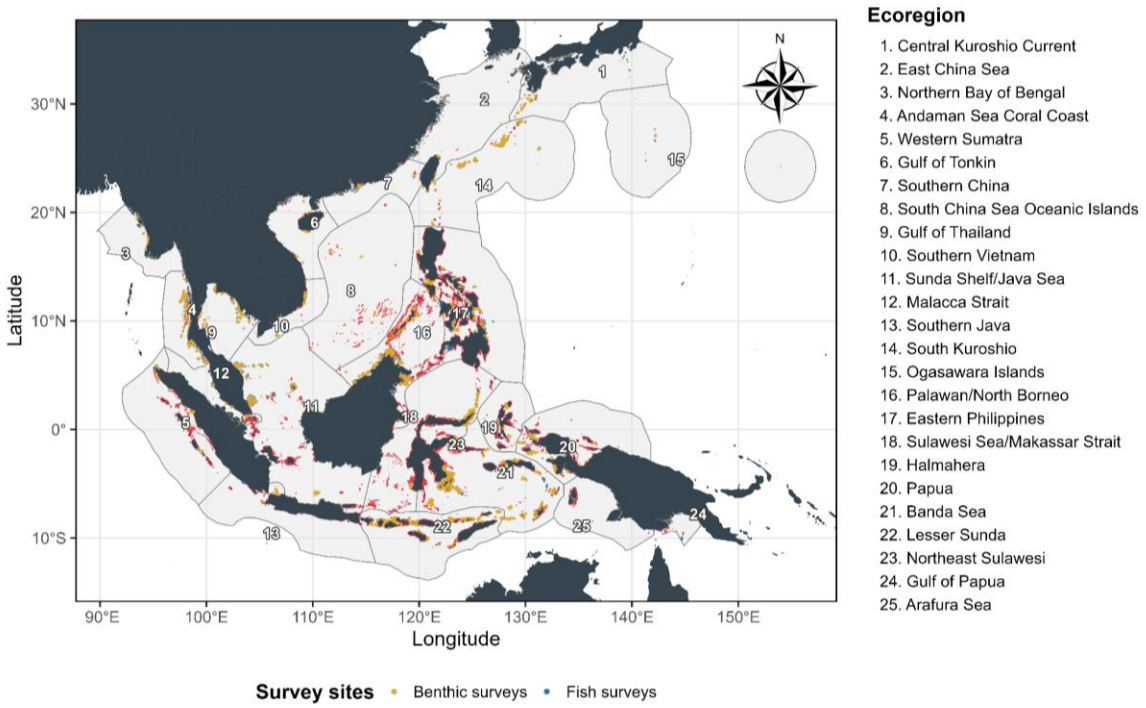


Figure 2 | Coral reefs of the East Asian region, grouped within 25 coral reef ecoregions (units of assessment, visualized in lightgrey) evaluated under the IUCN Red List of Ecosystems criteria and corresponding to Level 4 of the IUCN Global Ecosystem Typology. Coral reefs based on the UNEP-WCMC Millennium Coral Reef layer are shown in red. The 4,030 benthic monitoring sites used for the assessment of criteria A and D are shown in yellow, overlaid on the 2,009 reef fish monitoring sites used for the assessment of criterion D (blue), many of which are hidden beneath benthic sites.

1. Ecosystem Description

East Asia's photic coral reefs are biogenic carbonate structures formed primarily by hermatypic (reef-building) scleractinian corals and other associated calcifying organisms, which collectively form complex three-dimensional habitat. Reef morphology across the region ranges from dominant fringing reefs to platform reefs and atolls in the South China Sea Oceanic Islands, such as the Spratly Islands (Kimura et al., 2022). East Asia hosts the world's most biodiverse coral reefs (Veron et al., 2015). At its core, the region encompasses large parts of the Coral Triangle and extends northwards along the Kuroshio Current (Spalding et al., 2007). Across the region as a whole, scleractinian corals serve as the principal reef-builders in shallow tropical and subtropical waters, though their degree of dominance varies considerably from one setting to another. East Asian reefs are characterized by extraordinarily high levels of endemism, particularly in the Coral Triangle, in locations such as the Bird's Head Seascape and the Sulu–Sulawesi region (Allen, 2008; Huffard et al., 2012; Mora et al., 2003). In East Asia, accreting reefs (Type A) dominate across most of the region, while marginal reef systems (Type B) become locally important towards higher latitudes, as described in the reef typology section (Annex 9.2). Furthermore, these habitats provide crucial ecosystem services to coastal communities in some of the world's most densely

populated coastlines, including coastal protection, primary protein sources for millions of people and tourism revenue (Burke et al., 2002; Teh et al., 2013).

1.1. Key Biotic Components



Figure 3 | Diverse coral reef in Pulau Cemara Besar, Karimunjawa National Park, Indonesia. (Photo: Jibriel Firman, May 2026)

The coral reefs of East Asia are distinguished by the highest coral and fish biodiversity on the planet (Carpenter and Springer, 2005; Veron et al., 2009). For example, reefs in the Coral Triangle host more than 70% of all known scleractinian coral species and nearly 40% of the world's reef fishes (Allen, 2008; Veron et al., 2015). Coral species richness declines with increasing latitude towards marginal, non-reefal communities (Bellwood & Hughes, 2009; Hoeksema, 2007; Veron et al., 2015), where fewer than 200 species have been recorded at high latitudes in the East China Sea ecoregion (Yamano et al., 2011). From its core in the Coral Triangle, coral biodiversity also decreases westwards across the Sunda Shelf, where reefs in the Malacca Strait and Java Sea are dominated by turbidity-tolerant genera such as *Porites*, *Pectinia* and *Galaxea* (Huang et al., 2015; Mohd Safuan et al., 2018).

Reef fish species richness is also extraordinarily high in East Asia (Mora et al., 2003), with over 2,000 species in the most diverse ecoregions (Allen, 2008). For instance, the Bird's Head Seascape in Papua hosts an estimated 1,700 fish species around the peninsula (Allen, 2008), while other regions such as the Verde Island Passage in the central Philippines host similarly high numbers of shorefish species (Carpenter & Springer, 2005). Reef fish underpin multiple crucial ecological functions in coral reefs (Bellwood et al., 2004; Mora et al., 2011; Lefcheck et al., 2019), playing diverse and fundamental roles within these ecosystems. For instance, parrotfishes (Scarinae) and surgeonfishes (Acanthuridae) are key herbivores; many butterflyfishes (Chaetodontidae), wrasses (Labridae) and damselfishes (Pomacentridae) are

essential corallivores; and reef sharks, large groupers (Epinephelidae) and Napoleon wrasses (*Cheilinus undulatus*) are important predators. The dependence on a small number of species carrying out key ecological functions (low functional redundancy) has been documented for reefs with low species diversity such as those of the Malacca Strait, where macroalgal removal is sustained by a few abundant herbivore species (Bauman et al., 2017).

East Asian reefs further provide critical habitat for charismatic and threatened megafauna. For instance, six of the world's seven marine turtle species occur across the region, with major nesting sites located in eastern Indonesia, the Sulu Sea, eastern Malaysia and in the Andaman Sea (Ali et al., 2004). Furthermore, reef sharks, mobulid rays (*Mobula* spp.) and dugongs persist in remote locations but have been depleted across more accessible reefs by targeted fishing, the live reef fish trade and associated bycatch (Clark-Shen et al., 2023). Outbreaks of coral predators, such as the crown-of-thorns starfish (COTS; *Acanthaster* spp.) and *Drupella* snails are recurrent biotic disturbances across the region (Pratchett et al., 2014; Zhang et al., 2024).

1.2. Key Abiotic components

East Asian coral reefs are shaped by the combination of tropical and subtropical climates, major current systems, and the complex bathymetry of the Indo-Australian Archipelago. This region combines shallow continental zones (e.g. the Sunda Shelf, with an average depth of less than 50 m) with deep basins and trenches over 7,000 m deep. This complex seafloor topography strongly influences regional ocean currents and the exchange of water between the Pacific and Indian Oceans (Lohman et al., 2011). Sea surface temperatures generally range from 27–30°C in the tropical core, but are lower and more seasonally variable at higher latitudes around China, Taiwan and southern Japan. Thermal regimes across the region are strongly influenced by the El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD), which drive the interannual variability in bleaching risk (Luo & Lau, 2020; Eggeling et al., 2024; Gulakaram et al., 2026).

The Kuroshio Current is the dominant oceanographic feature at the northern margin of the region, transporting warm, oligotrophic water from the Philippines northwards along the Ryukyu Arc to southern Japan (Gallagher et al., 2015). The current is a major corridor for larval dispersal and is thus likely implicated in the ongoing poleward range expansion of tropical fishes and reef-building corals into subtropical reefs along Japan’s coast (Yamano et al., 2011; Vergés et al., 2014). In the south, the Indonesian Throughflow carries water from the Pacific Ocean through the Indonesian archipelago and into the Indian Ocean via the Makassar Strait as well as surrounding passages. This additional current system is also a key driver of larval connectivity and nutrient cycling across the East Asian region (Gordon, 2005; Huffard et al., 2012).

Turbidity and sedimentation regimes vary widely across the region. Offshore reefs in the South China Sea and outer Raja Ampat, as well as island chains such as the Ryukyu Archipelago, lie in clear and oligotrophic waters that support reef growth to depths of 30 m

or more. In contrast, inshore reefs in the Malacca Strait and in the Gulf of Tonkin are chronically turbid due to large riverine inputs and anthropogenic pressures such as land reclamation (Chou et al., 2019; Heery et al., 2018).

1.3. Key processes and interactions

The major ecological processes sustaining reef ecosystems in East Asia include calcium carbonate production, reef accretion, bioerosion, coral recruitment, herbivory, coral-algal competition and predation.

Scleractinian corals are the primary reef-builders in tropical and subtropical shallow environments, with distinct growth forms contributing differently to the three-dimensional framework (Zawada et al., 2019). Reef growth and persistence are a function of the balance between calcification and dissolution, as well as redistribution of calcium carbonate. Crustose coralline algae (CCA) and encrusting animals such as sponges and bryozoans further bind reef rubble and facilitate coral larval settlement (Mallela, 2013). In East Asian reefs, where species diversity of framework-builders is high, many organisms contribute to maintain accretion. Bioerosion by organisms that bore into, scrape, or chemically dissolve carbonate material weakens and breaks down the reef's carbonate structure, generating carbonate sediment that fills reef interstices and contributes to downstream reef formation. Key bioeroders include internal borers (boring sponges, tubeworms, and bivalves), grazers (parrotfish and sea urchins), and microborers (endolithic algae and fungi). On a healthy reef, gross carbonate production exceeds bioerosion, resulting in net reef accretion. When coral cover declines (e.g. following bleaching or Crown-of-thorns starfish (*Acanthaster* spp., henceforth 'COTS') outbreaks), bioerosion can exceed production, leading to reef erosion and loss of the three-dimensional framework (Tribollet & Golubic, 2011).

In locations with highly turbid waters, light limitation compresses reef development to shallower depths and selects for stress-tolerant assemblages dominated by massive *Porites* and Merulinidae corals (Chow et al., 2019; Morgan et al., 2020; Chan et al., 2023, 2024). Furthermore, in higher latitude regions such as Japan, low minimum sea temperatures and photosynthetically available radiation during winter restrict coral growth and carbonate accretion thus limiting the distribution of true coral reefs (Veron & Minchin, 1992; Higuchi et al., 2015; Muir et al., 2015).

Hard coral abundances are driven by death and recruitment, where the latter is modulated by larval production, dispersal, settlement and survival. Larval settlement can enhance recruitment and coral recovery in certain coral taxa (Gouezo et al., 2019; Harrison et al., 2021), and is in turn dependent on a wide range of biophysical factors such as wave exposure, available space as well as the presence of other benthic taxa, in particular CCA (Gouezo et al., 2020; Abdul Wahab et al., 2023; Edmunds, 2023). In East Asia, high connectivity among reefs via ocean currents (including the Indonesian Throughflow and Kuroshio Current) facilitates larval exchange across vast distances (Pata & Yñiguez, 2019). Post-settlement survival of juvenile corals is further mediated by ecological processes such as herbivory (which keeps

algae from overgrowing recruits), predation on juveniles by corallivores, and competition with other benthic organisms (Maida et al., 1994; Dunstan & Johnson, 1998).

Herbivory is critical for maintaining coral-dominated reefs in the region. Herbivorous fish, particularly parrotfish and surgeonfish, play a key role in keeping macroalgae in check, which would otherwise overgrow and outcompete corals for space and resources (Green & Bellwood, 2009). Other herbivore functional groups perform complementary roles. For example, scrapers and excavators (e.g. parrotfish) physically remove algae and underlying substrate, creating bare surfaces for coral settlement. Grazers and detritivores (e.g. surgeonfish and rabbitfish) crop algal turfs and prevent them from being succeeded by taller macroalgae. Browsers (e.g. rabbitfish and batfish) target established macroalgae and are critical for reversing algal overgrowth (Bejarano et al., 2019). Sea urchins (especially *Diadema* spp.) also contribute considerably to herbivory on East Asian reefs, providing a complementary grazing function to fish herbivores (Dang et al., 2020). On a healthy reef, herbivores continuously suppress algal biomass, and corals can outcompete neighbouring algae. Corallivores such as butterflyfish (Chaetodontidae), certain pufferfish (Tetraodontidae), tubelip wrasses (Labridae) and COTS consume live coral tissue (Cole et al., 2008), actively regulating coral community structure (Lenihan et al., 2011).

Healthy coral reefs in East Asia are typically sustained by the dynamic interplay of all of the processes mentioned above. Structural integrity is maintained when carbonate production by corals and CCA outpaces bioerosion, and benthic composition remains coral-dominated when herbivory is sufficient to suppress algal growth. Population replenishment depends on successful coral recruitment, which in turn requires suitable substrate maintained by herbivores, adequate larval supply from well-connected, healthy reproductive adult colonies, and low mortality. Trophic balance requires intact food webs where predators regulate prey populations, including controlling COTS outbreaks. Together, these processes can generate resilience against acute and chronic disturbances.

1.4. Main Threats

East Asian coral reefs face multiple interacting pressures that challenge their long-term persistence. Furthermore, severely degraded reefs have been shown to be more vulnerable to climate-driven disturbance (Burke et al., 2002, 2011). Using the IUCN Threat Classification Scheme, key threat categories are described below and summarised for each ecoregion in Table 1.

Fishing & harvesting aquatic resources (5.4)

Across East Asia, overfishing is one of the most severe and chronic threats to coral reef ecosystems (Kimura et al., 2022). The overexploitation of fish by commercial and artisanal fisheries is especially widespread in the Philippines, Indonesia, Vietnam, China and Malaysia (Pauly, 1987; Pomeroy, 2012). Moreover, destructive fishing practices including dynamite fishing, cyanide fishing and 'hookah' fishing (compressor driven gleaning), remain prevalent in parts of the region and cause the destruction of reef habitats as well as substantial harm to

non-target organisms (Burke et al., 2002, 2011). The live fish trade for food and marine aquaria exerts targeted pressures on ornamental species, key trophic taxa such as groupers, and threatened species such as Napoleon wrasse (Sadovy & Vincent 2002; Rhyne et al., 2017). Simultaneously, fish is crucial to regional cuisines, cultural identities and food security, underlining the importance of the long-term persistence of reef fish populations (Teh et al., 2013; Hicks et al., 2019).

One important impact of overfishing with significant consequences is the removal of herbivores. Herbivores maintain reefs in a coral-dominated state by removing competing algae. Yet in some East Asian reef systems, fishing pressure on herbivorous species (particularly parrotfish and rabbitfish) is intense (Bejarano et al., 2019). The release from herbivore pressure favours increasing dominance of macroalgae, which further reinforces a positive feedback loop through processes like shading of corals, abrasion via physical contact, spread of harmful microbial communities, and release of allelopathic compounds (Fong et al., 2020, 2023). The result is the heightened risk of phase shift from hard coral-dominant to macroalgal-dominant reefs.

Climate change & severe weather (11)

Ocean warming due to ongoing climate change causes thermal stress on coral reefs and represents one of the most significant threats to reef persistence across all ecoregions in East Asia (Kimura et al., 2022, 2026b). Mass coral bleaching events linked to elevated sea surface temperatures have caused substantial coral mortality during the global events of 1998, 2010 and 2014–2017, and most recently during the fourth global event of 2023–2025, which is the most extensive on record (Hughes et al., 2017; Eakin et al., 2026; Spady et al., 2026). Furthermore, the frequency and severity of bleaching events are projected to increase under all future emission scenarios (IPCC, 2022). Ocean acidification caused by the increasing amount of carbon dioxide dissolved in seawater further compounds climate risk due to increased stress on calcifying organisms such as corals, potentially slowing reef accretion and recovery (Eyre et al., 2018; Lam et al., 2019; Kay et al., 2023). The rise of sea levels observed in the last decades poses an additional threat to shallow reefs as well as to low lying reef islands. This is particularly concerning for the low-lying atolls in the South China Sea. Lastly, tropical cyclones can cause catastrophic physical damage to reef ecosystems in the western Pacific typhoon belt, particularly in the Eastern Philippines and South Kuroshio ecoregions, which openly face the Pacific Ocean (Harmelin-Vivien, 1994; Sully et al., 2022; Kuo et al., 2023).

Pollution (9)

Terrestrial runoff carrying sediments, nutrients, and pollutants from intensive agriculture, mining, and urbanisation degrades nearshore reef environments across nearly all ecoregions. These environmental impacts are exacerbated by deforestation. Sedimentation is particularly severe in the Malacca Strait, Gulf of Tonkin, Sunda Shelf, and Borneo, where palm oil plantation expansion and mining have dramatically increased sediment loads (Jakobsen et al., 2007). Nutrient enrichment from agricultural and domestic waste enhances eutrophication, promoting algal growth near already degraded reefs.

Sedimentation due to coastal development and land reclamation throughout the region also contributes to long-term coral reef degradation (Yeemin et al., 2013; Chan et al., 2024; Loong et al., 2025). Sediment can physically abrade and smother corals by generating an anoxic microenvironment under layers of deposited material (Bollati et al., 2022; Jones et al., 2019; Rogers, 1990). Suspended sediment also increases water turbidity, which limits the growth and survival of corals (Dikou & van Woesik, 2006; Chow et al., 2019; Morgan et al., 2020).

Marine debris and microplastics are emerging stressors in multiple ecoregions, and corals can act as long-term sinks for microplastics, which become embedded in their skeletons (Reichert et al., 2022). Oil spills, industrial effluents as well as heavy metals from shipping and mining add further stressors, particularly along the world's busiest shipping routes in the Malacca Strait and South China Sea (Foo et al., 2024).

Residential and commercial development (1)

Coastal development is accelerating due to urbanization. This fast development is also facilitated by the expansion of tourism infrastructure and port construction. Tourism overdevelopment generates localised impacts including sewage discharge and physical damage from recreational activities (Huang et al., 2006; Reopanichkul et al., 2010; Wongthong & Harvey, 2014). Land reclamation has been particularly destructive as large-scale dredging has caused irreversible loss of reef habitat. For example, land reclamation has increased Singapore's land area by more than 20% since the 1950s (Tan et al., 2023), resulting in substantial reductions in reef area (Chou et al., 2019). Further reclamation continues to threaten the persistence of the remaining reefs.

Invasive and problematic species (8)

Crown-of-thorns starfish (COTS; *Acanthaster* spp.) outbreaks are among the most significant biotic threats to reef ecosystem stability. Outbreaks documented in the Ryukyu Islands, South China Sea Oceanic Islands, and across the Coral Triangle were likely caused by a combination of both bottom-up and top-down drivers (Nakamura et al., 2014; Chen et al., 2021). For example, nutrient enrichment from terrestrial runoff has been proposed to contribute to higher larval recruitment, while overfishing of predators reduces predation pressure on COTS (Babcock et al., 2016; Meekan et al., 2025).

Table 1 | Occurrence of major threats impacting coral reefs in each ecoregion categorised based on the IUCN Threat Classification Scheme. Ecoregions were ordered based on the groupings and sequence of Marine Ecoregions of the World (MEOW) outlined in Spalding et al., (2007). Documented threats are marked with '✓', emerging threats are marked with '+', and threats which are absent/unlikely to arise are marked with '-'. Some cells are left blank to reflect the uncertainty of those threats in various ecoregions, as these have not yet been documented as present, absent, or emerging. Ecoregion numbers (1–25) correspond to those in Figure 2.

Threat type	Subcategory	Ecoregion																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
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	-							+						-	-	✓	+								
	3.2 Mining & quarrying	-			✓		✓		-						✓	-	✓	✓		✓	✓			✓		
4. Transportation & service corridors	4.3 Shipping lanes	-					✓		-				✓		-	-	+	+								
5. Biological resource use	5.4 Fishing & harvesting aquatic resources	✓				✓		✓	✓			✓	✓		✓	-	✓	✓	✓	✓		✓	✓	✓	+	✓
6. Human intrusions & disturbance	6.1 Recreational activities	-							-						-	-	-	-								
7. Natural system modifications	7.3 Other ecosystem modifications	✓	+		✓				✓			✓	✓		✓	-	✓	✓	✓	✓	✓		✓	✓		✓
8. Invasive & problematic species	8.1 Invasive non-native species	-	✓					✓	-						-	-	-	-						✓		
9. Pollution	9.1 Domestic & urban waste water	-							✓				✓	✓	-	-	✓	✓		✓	✓	✓	✓			✓
	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	✓	✓		✓	✓	✓	✓	✓				✓		✓	✓	✓	✓								

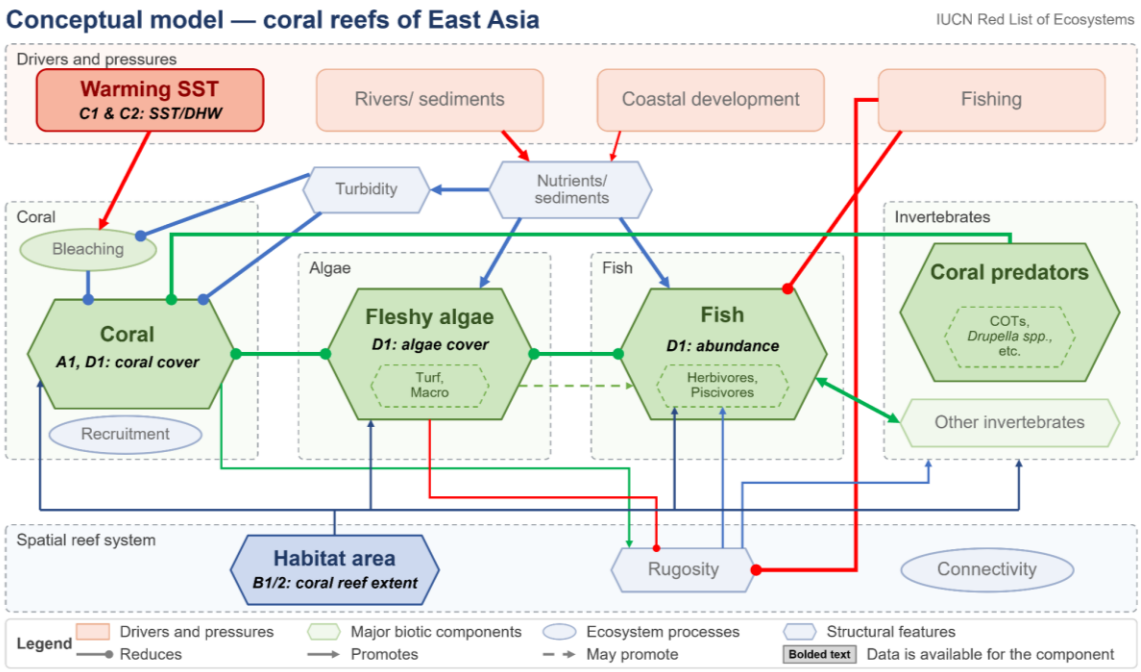


Figure 4 | Conceptual model of East Asia's coral reef ecosystems. The model illustrates key biotic and abiotic components, as well as external drivers, threats, and the processes and interactions between them. All sub-criteria that have been analyzed are highlighted in italics.

1.5. 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 a number of pathways that reduce the capacity of an ecosystem to sustain its characteristic biota, such as disease, overharvesting, or a persistent change in environmental conditions. Collapse can occur locally, for example in 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 signaled 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 characterized by a phase shift from coral dominance to high abundances of other benthic components, such as turf and fleshy algae, rubble, and 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 a simplified topographic structure or occurs where the geomorphological structure of coral reefs permanently disappears through land reclamation or coastal development. A collapsed reef may have an unsuitable abiotic environment due to declines in water quality, increases in temperature, as well as frequent and severe disturbance events.

Under the Red List of Ecosystems framework, collapse can be defined as when 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:

1. complete loss of coral reef area (Criterion A, defined as all monitoring sites below 10% coral cover)
2. hard coral cover falling below 5 % (Criterion D)
3. sea surface temperatures exceeding critical thresholds, resulting in frequent severe heatwaves that cause coral bleaching at an average return interval of 3 years or less over a 30-year period or that occur 3 times within 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:

1. an algal-to-coral cover ratio exceeding 5:1;
2. severe depletion of key fish groups (e.g. herbivores and piscivores) to levels well below historical baselines.

Table 2 | Key abiotic and biotic features and characteristics of the coral reef's ecoregions in East Asia highlighting unique aspects of each ecosystem.

Ecoregion	Key Biotic	Key Abiotic	Key Threats
1 - Central Kuroshio Current	The northernmost limit of northern reef development is located around Yakushima and Tanegashima. Sites further north are predominantly rocky reefs or non-reefal.	The Kuroshio current moderates temperature and population connectivity.	COTS outbreaks, cold water stress, bleaching, typhoons, tropicalisation, climate warming
2 - East China Sea	Reefs in Taiwan are marginal, and reefs in Jeju are predominantly rocky and soft coral-dominated. Relatively high dominance of non-reef-building coral communities, soft coral assemblages, and macroalgae. Some areas reported to undergo tropicalisation of benthic taxa from macroalgae- to coral-dominated.	Coral growth modulated by the Tsushima Warm Current and progressively lower temperatures at higher latitude.	Bleaching, typhoons, sedimentation and nutrient enrichment, tropicalisation, climate warming
3 - Northern Bay of Bengal - Myanmar	Coral communities dominated by *Acropora* and *Porites*; diverse reef fish; reef-associated invertebrates	Mixed fringing reefs and offshore reefs; monsoon-driven currents; variable turbidity	Overfishing, sedimentation, coastal development
4 - Andaman Sea Coral Coast	Majority of reefs in ecoregion are fringing, with extensive intertidal reefs.	Relatively consistent annual temperature range. Indian Ocean Dipole introduces higher variance into tidal heights, which potentially affects the exposure of corals.	Dredging, mining, climate warming

Ecoregion	Key Biotic	Key Abiotic	Key Threats
5 - Western Sumatra	Dead coral and other abiotic substrates mainly drive benthic cover. Reefs around Aceh are exceptional, and exposed to the waters from the Indian Ocean, Andaman Sea, and Malacca strait. Formerly dominant *Acropora formosa* and *A. nobilis* conspicuously absent or under-represented after the 1997 die-off.	Indian Ocean Dipole, which formerly resulted in an abnormal upwelling and low temperature event resulting in a coral die-off event in 1997.	Pollution, sedimentation, agricultural impacts
6 - Gulf of Tonkin	Dominated by stress-tolerant taxa like *Porites* and *Favites*. Presence of reefs with 'typical' seaward/vertical zonation, and "encrusting reefs" without clear spatial structure	High sediment load from river discharge. Predominantly shallow (50-60 m, not exceeding 100 m), and annual temperature range is relatively large. Experiences summer upwellings.	Pollution, land reclamation, overfishing, aquaculture, salinisation and local freshening, typhoons, dredging, extreme water temperatures
7 - Southern China	Sporadic fringing reefs around Hainan Island, limited reef occurrence along the mainland coast.	Waters range from clear to turbid, but are very turbid in developed areas.	Pollution, COTS outbreaks, overfishing, coastal development, aquaculture, tourism
8 - South China Sea Oceanic Islands	Composed of platform reefs and atolls formed around the Spratly Islands in the west, the Paracel Islands in the northwest, and dispersed islands and seamounts in the south.	Reef waters typically clear.	Destructive fishing and overfishing, land reclamation, sea level rise
9 - Gulf of Thailand	Dominated primarily by stress-tolerant *Porites*, and secondarily by *Pavona, Diploastrea,* and *Acropora* spp. Offshore reef sites typically have higher coral cover and diversity, with higher abundance of *Acropora* spp. Reef fish and invertebrate grazers indicated to contribute to overall reef health	Monsoon seasons, and nutrient-rich sediment input from major river outflows.	Fishing, eutrophication sedimentation, coastal development, tourism, bleaching
10 - Southern Vietnam	It comprises both mainland reef areas (south of central Vietnam), and offshore reefs (notably around Con Dao and Nha Trang). Reef health is typically higher on offshore sites based on coral cover and macroalgae as indicators.	Monsoon-driven upwelling moderates thermal stress from May to August. River discharge and high turbidity constrains reef formation.	COTS outbreaks, overfishing, aquaculture, dredging and dumping, coastal development, climate warming, bleaching
11 - Sunda Shelf/Java Sea	Coral reefs with high coral species richness. Typically dominated by foliose and massive coral taxa, but occasionally includes reefs dominated by branching	Temperature and salinity are generally stable, with some seasonal (monsoonal) variation, especially along the east	Overfishing, marine debris including "ghost nets", aquaculture, tourism,

Ecoregion	Key Biotic	Key Abiotic	Key Threats
	Montipora and *Acropora* spp. Algae is the most common benthic taxa, typically comprising turf algae or biofilm. Presence of high trophic level predators suggest relatively intact trophic structures	coast of Peninsular Malaysia.	coastal development, climate warming, bleaching
12 - Malacca Strait	The lower limit of reef formation is shallow (~10 m), and reefs are dominated by stress- and turbidity-tolerant coral taxa (*Porites* spp., Merulinidae). Low structural complexity, and low herbivore diversity but macroalgae removal rates sustained by a small number of dominant fish species.	Severe turbidity from both natural and anthropogenic sources, with high resuspension and strong currents	Land reclamation, high turbidity, chronic sedimentation, coastal development, shipping, pollution, overfishing, thermal stress
13 - Southern Java	Reefs located along the southern coasts of the West Java province, Banten province, and the northern coast directly west of Jakarta. Offshore reefs are present in the Thousand Islands archipelago and Panaitan Island. Reef condition generally improves with distance from populated areas and associated anthropogenic stressors.	Reefs on the southern coast experience both heat and cold stress events, driven by strong ENSO and positive IOD events respectively.	Pollution, climate warming
14 - South Kuroshio	Predominantly fringing reefs. High diversity of reef building coral assemblages, with species richness declining northwards. Distinct latitudinal boundary between low-latitude, reef-building coral communities, and high-latitude, non-reef-building coral communities.	The Kuroshio Current acts as a dispersal corridor for larval fish, corals, and other invertebrates, from the northwestern Philippines to higher latitudes, enabling reef development even at northern sites.	Bleaching, climate warming, typhoons, sedimentation, coastal development
15 - Ogasawara Islands	Highly isolated oceanic archipelago ~1,000 km south of Tokyo, supporting over 200 reef-building coral species.	Exposed to the open ocean, with presence of upwelling from deep waters, and the limited extent of shallow coastal areas.	Coral bleaching, localized impacts from, red soil runoff, coastal development
16 - Palawan/North Borneo	High habitat heterogeneity, including different types of reefs. High diversity and endemicity of reef fish species. Globally important as a critical nesting site for the green sea turtle (*Chelonia mydas*).	Semi-enclosed sea with a deep basin (~5,000 m), with mixing driven by internal waves.	Destructive fishing and overfishing, coastal development, plastic pollution and marine debris, extensive logging and mining, sedimentation, bleaching, climate warming

Ecoregion	Key Biotic	Key Abiotic	Key Threats
17 - Eastern Philippines	High diversity of reef building corals. The central Philippines has the highest diversity of marine invertebrates and shore fish.	Reefs experience seasonal (monsoonal) variations.	Destructive fishing and overfishing, coastal development, plastic pollution and marine debris, bleaching, climate warming
18 - Sulawesi Sea/Makassar Strait	Upwelling from the Indonesian Throughflow (ITF) supports high coral and fish diversity. This ecoregion hosts ecologically important features such as cetacean migration routes, and houses rare fish species like the Indonesian coelacanth (*Latimeria menadoensis*).	The Indonesian Throughflow (ITF) facilitates water movement from the Pacific to the Indian Ocean, primarily through the Makassar Strait, enhancing larval connectivity, cooling and bringing freshwater to the Indian Ocean. The ITF also drives upwelling in various offshore and nearshore areas.	Destructive fishing and overfishing, marine debris, climate warming
19 - Halmahera	Complex range of habitats, with leeward reefs and sites open to pacific swells, several volcanic islands, and underwater seamounts. It is part of the continuum of the Sulu-Sulawesi Sea, and features high coral and fish species diversity and endemicity. It has the highest per unit area richness of coral species	The Indonesian Throughflow drives upwelling, bringing cool water and nutrients to surface layers.	Destructive fishing and overfishing, coastal mining, eutrophication leading to harmful algal blooms
20 - Papua	Highest fish diversity in the coral triangle; very high coral species diversity. High degree of endemicity among various taxa, including leatherback turtles, reef sharks, mobulid rays, Napoleon wrasse, and various cetaceans and dugongs.	High temperature variability. Transition zone between Pacific Ocean and Indonesian seas. South Equatorial Current flows westwards and merges into the Halmahera Eddy.	Coastal mining, resource exploitation, unregulated coastal development
21 - Banda Sea	Hosts high coral diversity and endemicity. Habitat heterogeneity is high, ranging from relatively shallow coral reefs to isolated oceanic environments (~5000 m), upwelling and downwelling cells, and volcanically active basins.	A large proportion of the ecoregion comprises shelf areas shallower than 200 m. Highly heterogenous, tectonically active ocean setting, with high degree of isolation across habitats. Several upwelling events are suggested to mitigate coral bleaching from thermal stress.	Destructive fishing and overfishing, pollution
22 - Lesser Sunda	High coral and fish diversity, and high rate of endemism.	Seasonal upwelling and higher wave energy along the southern coast than the northern coast. Hydrodynamic forcing drives nutrient mixing, larval dispersal, and reef connectivity. Upwelling zones enhance	Destructive fishing and overfishing, pollution, coastal development, climate warming, sea level rise, tourism

Ecoregion	Key Biotic	Key Abiotic	Key Threats
		productivity and influence coral distribution and growth.	
23 - Northeast Sulawesi	Characterized by very high coral and high fish species richness. Consists of various reef types found in a contiguous system.	Deep bathymetry (up to 3,000 m), with several upwelling sites. The inner bay environment supports high larval connectivity.	Destructive fishing and overfishing, mining, COTS outbreaks, sedimentation, pollution
24 - Gulf of Papua	Low-reef-development setting bordered by areas with major reef systems. Coral communities are developed on hard substrates and rubble banks away from the main influence of the Fly River. Combination of mangrove-dominated coastlines, sparse narrow fringing reefs, river-influenced inshore turbidity and coral communities restricted to rubble banks and hard substrates away from major rivers.	Waters are mostly clear offshore but turbid nearshore. Mixing and freshwater discharge from river systems may potentially explain observed patterns in fish assemblages.	Several highly endangered elasmobranch taxa are threatened both by small-scale targeted fishing (Grant et al., 2021), and by commercial trawling. The latter has the potential to become a more substantial threat through upscaling (Baje et al., 2021).
25 - Arafura Sea	Coral species richness is lower than in the core Coral Triangle. This ecoregion is important for rays and sawfishes, cetaceans, dugongs, and turtles. Vertebrate diversity is relatively high. Extensive pristine non-reef habitats. Potentially serves as a biogeographic link between Papua and Sulawesi, and more broadly between the Indonesian archipelago and Australia.	Shallow (~90 m), semi-enclosed tropical shelf sea at the southern margin of the Coral Triangle. High turbidity due to sedimentation from multiple river inputs.	Overfishing, poaching, terrestrial runoff and sedimentation, coastal development

2. Criterion Assessment

Coral reefs in **25** ecoregions within the **East Asian region** 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.

Criterion A — Decline in 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 10% 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.

Criterion B — Restricted Geographic Distribution

Criterion B assesses the extent of occurrence (EOO) and area of occupancy (AOO) of the current distribution of coral reefs. EOO is the total area within the outer limits of the ecosystem's distribution, while AOO is the area occupied by the ecosystem, measured as the number of 10 by 10 km grid cells. Both were derived using the Millennium Coral Reef Layer, validated by regional experts. For both metrics the thresholds from the RLE guidelines were applied to assess risk, and additional conditions on continuing decline were evaluated using threat and biotic data from Criteria C and D.

Criterion C — Environmental Degradation

Criterion C evaluates the degradation of the abiotic environment and the risk this poses to ecosystem persistence. Globally, the most pertinent threat to coral reefs is the increasing occurrence of extreme marine heatwave events that cause coral bleaching and mortality. Under Criterion C, we evaluated historical changes in frequency of marine heatwaves 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 2-3 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 C2 was taken as the final risk status under Criterion C.

Criterion D — Disruption of Biotic Processes and Interactions

Criterion D assesses the disruption to 4 key biotic components over the past 50 years. This includes coral cover, algae-to-coral ratio, herbivore abundance, and piscivore abundance 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, step-wise approach across all indicators is applied to derive the overall risk status under Criterion D for each ecoregion.

Table 3 | Methodology, parameters and collapse thresholds used to assess coral reef ecosystems in East Asia under the Red List of Ecosystem criteria.

Criterion	Sub-criterion	Indicator(s)	Data Sources	Collapse Threshold(s)	Criterion Assessed? (Yes/No)	Comments
A - Reduction in geographic distribution	A1 – (Past 50 years)	Reef habitat benthic cover	GCRMN monitoring dataset; monitoring datasets accessed through the MERMAID data portal; YKAN project dataset	10% coral cover indicating local collapse	Yes	Based on reef survey time series. Given the generally high hard coral cover across East Asia, a 10% threshold was used to define collapse. Note that this parameter is higher compared to the 5% collapse threshold used for most other regions.
B - Restricted geographic distribution	B1 – Extent of Occurrence (EOO)	Extent of Occurrence (EOO) + ongoing decline or number of threat defined locations	Millennium Coral reef extent layer, regional reef maps, expert knowledge	Collapse when the mapped reef distribution declines to zero. CR ≤2,000 km^2, EN ≤20,000 km^2, VU ≤50,000 km^2, NT ≤55,000 km^2 of EOO, with ongoing decline or threats.	Yes	Calculated per ecoregion as minimum convex polygons using the makeEOO and getAreaEOO functions from the *redlistr* R package (v2.0.0, Lee et al., 2017).
	B2 – Area of Occupancy (AOO)	Area of Occupancy (AOO) + ongoing decline or number of threat defined locations	Millennium Coral reef extent layer, Grid-based reef presence (10×10 km), monitoring data	Collapse when the mapped reef distribution declines to zero. CR ≤2, EN ≤20, VU ≤50, NT ≤55 grid cells of AOO, with ongoing decline or threats.	Yes	Grid calculated using makeAOOGrid function from the *redlistr* R package (v2.0.0, Lee et al., 2019). Grid cells with reef area <1% of cell excluded.
C - Environmental degradation	C1 – Environmental degradation	Degree Heating Weeks (DHW), bleaching history	NOAA Coral Reef Watch	Return interval of ≤ 3 years between bleaching events or 2-3 severe mortality events within 5 years	Yes	Past 50 years (1975–2025), chronic and pulse pathways; long-term observed warming trend assessed
	C2 – Projected future degradation	Degree Heating Weeks (DHW)	Modelled global DHW projections (Mellin et al., 2024)	Return interval of ≤ 3 years between bleaching events or 2–3 severe mortality events within 5 years	Yes	SSP2–4.5 (primary) and SSP3–7.0
D - Disruption of biotic processes and interactions	D1 – Disruption of biotic processes	Hard coral cover, Algae-coral ratio, Parrotfish	Benthic cover & fish counts from UVC	Hard coral cover ≤ 5%, ACR = 0.833 (5:1);	Yes	Data sparse in some ecoregions and for some

Criterion	Sub-criterion	Indicator(s)	Data Sources	Collapse Threshold(s)	Criterion Assessed? (Yes/No)	Comments
		abundance (Herbivory), Groupers abundance (Piscivory)	surveys (different methods)	Groupers: 20% of initial levels Parrotfish: 10% of initial levels		indicators (were defined as data deficient and not evaluated)

3. Risk Status

Coral reefs across **all** ecoregions of **East Asia** are at a high risk of collapse. **All** of the **25 ecoregions** are classified as Critically Endangered across all criteria, and this status was driven by the risk due to projected ocean warming (sub criterion C2). Based on observed changes alone (Criteria A, B, C1 and D), **22** of the **25** ecoregions, accounting for more than 78.8 % of the mapped coral reef area, are classified in a threatened category. Of these, five are Critically Endangered (CR), ten Endangered (EN) and seven Vulnerable (VU). These risk statuses are mainly driven by recurrent heat stress at the margins of the region (sub-criterion C1) as well as by depleted parrotfish and grouper stocks (Criterion D). C1 drove the status of all five Critically Endangered ecoregions. Only the Sunda Shelf/Java Sea, the Eastern Philippines and Halmahera are assessed as Near Threatened (NT) based on these criteria, with no ecoregions considered Least Concern.

Table 4 | Summary of RLE assessment results for East Asian coral reef ecoregions. The overall Red List of Ecosystems status is the highest level of risk identified across all the assessed criteria. C1 and C2 show the risk due to observed and projected ocean warming. The criteria driving the observed risk status are shown in brackets.

Ecoregion	A	B	C1	C2	D	Risk - observed (A, B, C1, D)	Overall
1 - Central Kuroshio Current	LC	EN	CR	CR	VU	CR (C1)	CR
2 - East China Sea	LC	VU	CR	CR	VU	CR (C1)	CR
3 - Northern Bay of Bengal - Myanmar	LC	VU	EN	CR	VU	EN (C1)	CR
4 - Andaman Sea Coral Coast	LC	LC	VU	CR	VU	VU (C1, D)	CR
5 - Western Sumatra	LC	LC	LC	CR	VU	VU (D)	CR
6 - Gulf of Tonkin	LC	LC	EN	CR	VU	EN (C1)	CR
7 - Southern China	LC	VU	CR	CR	EN	CR (C1)	CR
8 - South China Sea Oceanic Islands	VU	LC	NT	CR	DD	VU (A)	CR
9 - Gulf of Thailand	LC	LC	VU	CR	VU	VU (C1, D)	CR
10 - Southern Vietnam	EN	VU	VU	CR	EN	EN (A, D)	CR
11 - Sunda Shelf/Java Sea	LC	LC	NT	CR	NT	NT (C1, D)	CR
12 - Malacca Strait	LC	LC	NT	CR	VU	VU (D)	CR
13 - Southern Java	LC	LC	EN	CR	VU	EN (C1)	CR
14 - South Kuroshio	NT	LC	EN	CR	EN	EN (C1, D)	CR
15 - Ogasawara Islands	LC	CR	CR	CR	LC	CR (B, C1)	CR
16 - Palawan/North Borneo	LC	LC	VU	CR	EN	EN (D)	CR
17 - Eastern Philippines	NT	LC	NT	CR	NT	NT (A, C1, D)	CR
18 - Sulawesi Sea/Makassar Strait	LC	LC	NT	CR	VU	VU (D)	CR
19 - Halmahera	LC	LC	NT	CR	DD	NT (C1)	CR
20 - Papua	LC	LC	LC	CR	EN	EN (D)	CR

Ecoregion	A	B	C1	C2	D	Risk - observed (A, B, C1, D)	Overall
21 - Banda Sea	LC	LC	VU	CR	EN	EN (D)	CR
22 - Lesser Sunda	LC	LC	LC	CR	EN	EN (D)	CR
23 - Northeast Sulawesi	LC	LC	VU	CR	VU	VU (C1, D)	CR
24 - Gulf of Papua	DD	VU	CR	CR	DD	CR (C1)	CR
25 - Arafura Sea	DD	LC	EN	CR	DD	EN (C1)	CR

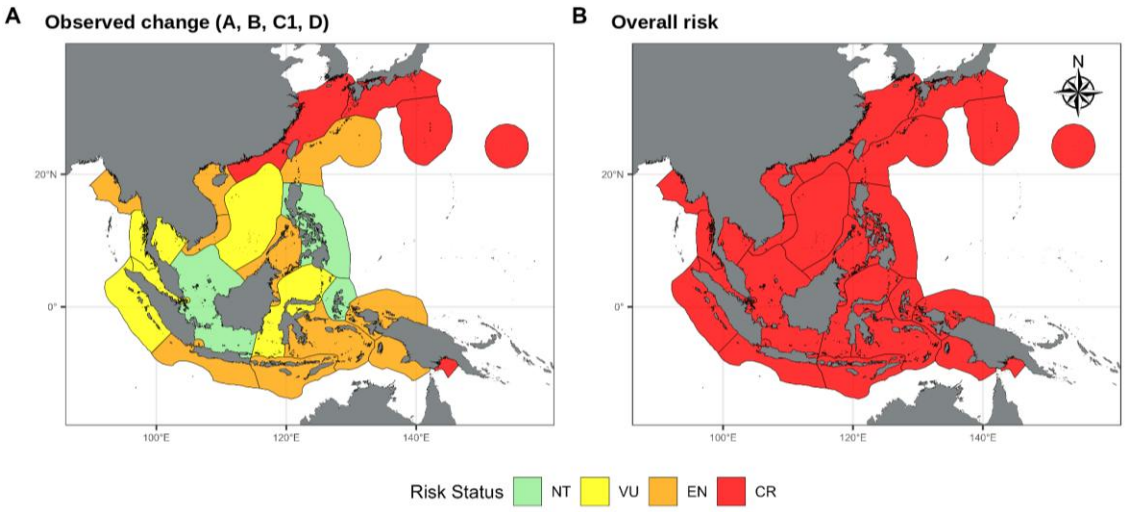


Figure 5 | Red List of Ecosystems risk status for the 25 East Asian ecoregions evaluated. A depicts the risk status arising from observed change over the past 50 years, taken as the highest risk returned by criteria A, B, C1 and D. B shows the overall risk status, which includes projected ocean warming under sub-criterion C2, based on forecasted ocean warming over the next 50 years (2026–2075) under SSP2–4.5.

Criterion A: Reduction in Geographic Distribution

Of the **23** ecoregions assessed, **2** are classified within threatened categories (Vulnerable, Endangered or Critically Endangered), having lost a significant area of their coral reefs over the past 50 years. In some ecoregions, particularly **Southern Vietnam** and **South China Sea Oceanic Islands**, which are historically known for having high average coral cover (Hughes et al., 2013; Tkachenko et al., 2023), reef loss exceeded **44%**, highlighting areas of concern where **cumulative pressures such as coastal development (including land reclamation), sedimentation, and destructive fishing practices** are highest. **21** ecoregions are assessed as Least Concern or Near Threatened, as well as **2** ecoregions (Gulf of Papua and Arafura Sea) as Data Deficient.

Table 5 | Risk status of **East Asian** coral reef ecoregions under Criterion A, determined from estimated declines in coral reef area over the last 50 years.

Coral Reef Ecoregion	Proportion of reef sites below critical hard coral cover threshold (10%)	Risk status under Criterion A1
1 - Central Kuroshio Current	11.6%	LC

Coral Reef Ecoregion	Proportion of reef sites below critical hard coral cover threshold (10%)	Risk status under Criterion A1
2 - East China Sea	0.0%	LC
3 - Northern Bay of Bengal - Myanmar	14.3%	LC
4 - Andaman Sea Coral Coast	5.1%	LC
5 - Western Sumatra	12.2%	LC
6 - Gulf of Tonkin	12.0%	LC
7 - Southern China	2.6%	LC
8 - South China Sea Oceanic Islands	44.4%	VU
9 - Gulf of Thailand	2.1%	LC
10 - Southern Vietnam	50.9%	EN
11 - Sunda Shelf/Java Sea	2.5%	LC
12 - Malacca Strait	9.5%	LC
13 - Southern Java	18.2%	LC
14 - South Kuroshio	28.9%	NT
15 - Ogasawara Islands	0.0%	LC
16 - Palawan/North Borneo	8.6%	LC
17 - Eastern Philippines	27.3%	NT
18 - Sulawesi Sea/Makassar Strait	0.6%	LC
19 - Halmahera	0.0%	LC
20 - Papua	9.8%	LC
21 - Banda Sea	10.6%	LC
22 - Lesser Sunda	4.6%	LC
23 - Northeast Sulawesi	0.0%	LC
24 - Gulf of Papua	-	DD
25 - Arafura Sea	-	DD

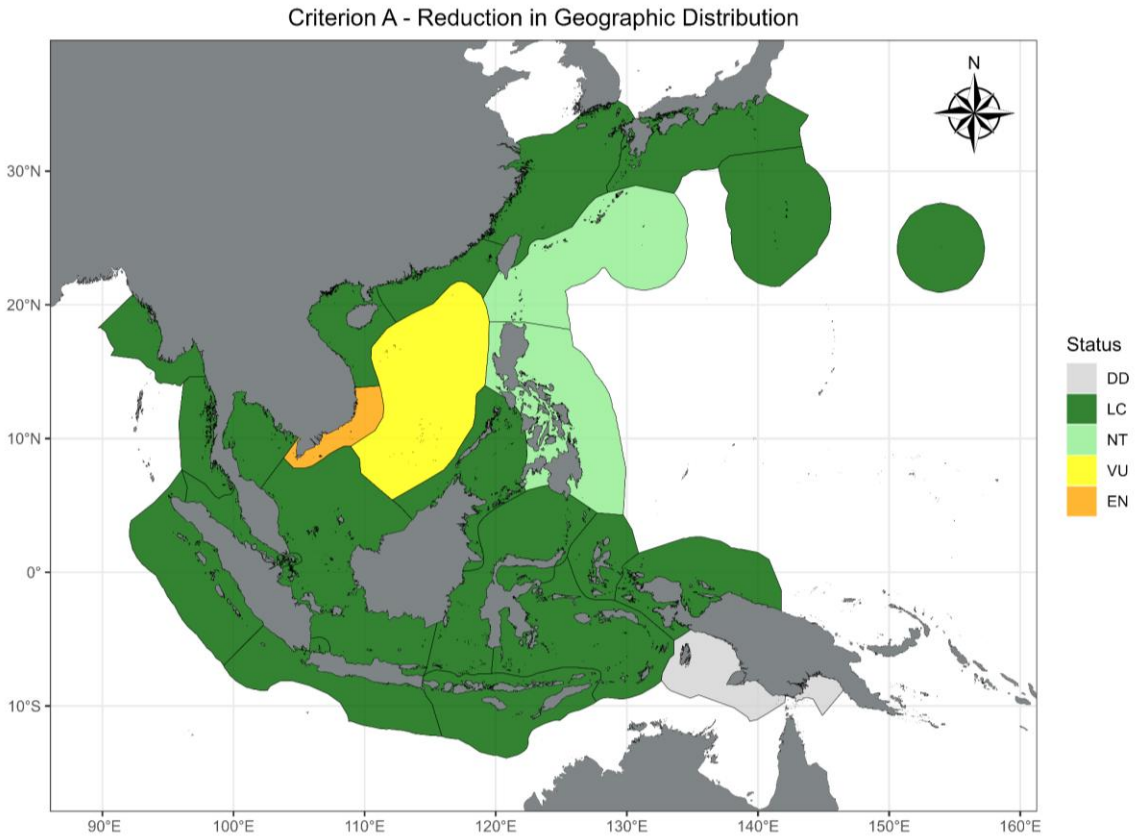


Figure 6 | Risk status under Criterion A (reduction in geographic distribution) based on the proportion of monitoring sites that have fallen below 10% hard coral cover over the past 50 years.

Criterion B: Restricted Geographic Distribution

Under Criterion B, **7** of the **25** ecoregions are assessed as **Vulnerable**, **Endangered** or **Critically Endangered**, while the remaining **18** are assessed as **Near Threatened (NT) or Least Concern**. Ecoregions with a small extent of accreting coral reefs such as the **Ogasawara Islands** and the **Central Kuroshio Current**, meet the thresholds for restricted EOO or AOO respectively, especially when combined with ongoing threats such as coral bleaching.

Table 6 | Risk status of **East Asian** coral reef ecoregions under Criterion B, determined from distribution of coral reefs measured as the Extent of Occurrence (EOO) and Area of Occupancy (AOO).

Coral Reef Ecoregion	Extent of Occurrence (B1) EOO (km²)	Area of Occupancy (B2) AOO	Risk status under B1 and B2	Risk Status under Criterion B
1 - Central Kuroshio Current	10,888.33	21	B1: EN / B2: VU	**EN**
2 - East China Sea	199,466.41	39	B1: LC / B2: VU	**VU**
3 - Northern Bay of Bengal - Myanmar	41,641	74	B1: VU / B2: LC	**VU**
4 - Andaman Sea Coral Coast	116,150.59	167	B1: LC / B2: LC	**LC**
5 - Western Sumatra	231,578.42	415	B1: LC / B2: LC	**LC**
6 - Gulf of Tonkin	266,920.77	61	B1: LC / B2: LC	**LC**

Coral Reef Ecoregion	Extent of Occurrence (B1) EOO (km²)	Area of Occupancy (B2) AOO	Risk status under B1 and B2	Risk Status under Criterion B
7 - Southern China	73,761.19	26	B1: LC / B2: VU	VU
8 - South China Sea Oceanic Islands	1,031,657.08	345	B1: LC / B2: LC	LC
9 - Gulf of Thailand	186,300.79	89	B1: LC / B2: LC	LC
10 - Southern Vietnam	65,528.67	45	B1: LC / B2: VU	VU
11 - Sunda Shelf/Java Sea	1,659,635.22	503	B1: LC / B2: LC	LC
12 - Malacca Strait	124,806.63	81	B1: LC / B2: LC	LC
13 - Southern Java	201,560.67	125	B1: LC / B2: LC	LC
14 - South Kuroshio	654,753.65	203	B1: LC / B2: LC	LC
15 - Ogasawara Islands	2.33	1	B1: CR / B2: CR	CR
16 - Palawan/North Borneo	868,332.52	1015	B1: LC / B2: LC	LC
17 - Eastern Philippines	686,999.72	1174	B1: LC / B2: LC	LC
18 - Sulawesi Sea/Makassar Strait	956,387.63	606	B1: LC / B2: LC	LC
19 - Halmahera	121,574.70	238	B1: LC / B2: LC	LC
20 - Papua	389,931.27	454	B1: LC / B2: LC	LC
21 - Banda Sea	975,237.30	922	B1: LC / B2: LC	LC
22 - Lesser Sunda	535,467.46	502	B1: LC / B2: LC	LC
23 - Northeast Sulawesi	76,011.03	131	B1: LC / B2: LC	LC
24 - Gulf of Papua	55,778.24	48	B1: LC / B2: VU	VU
25 - Arafura Sea	151,888.47	70	B1: LC / B2: LC	LC

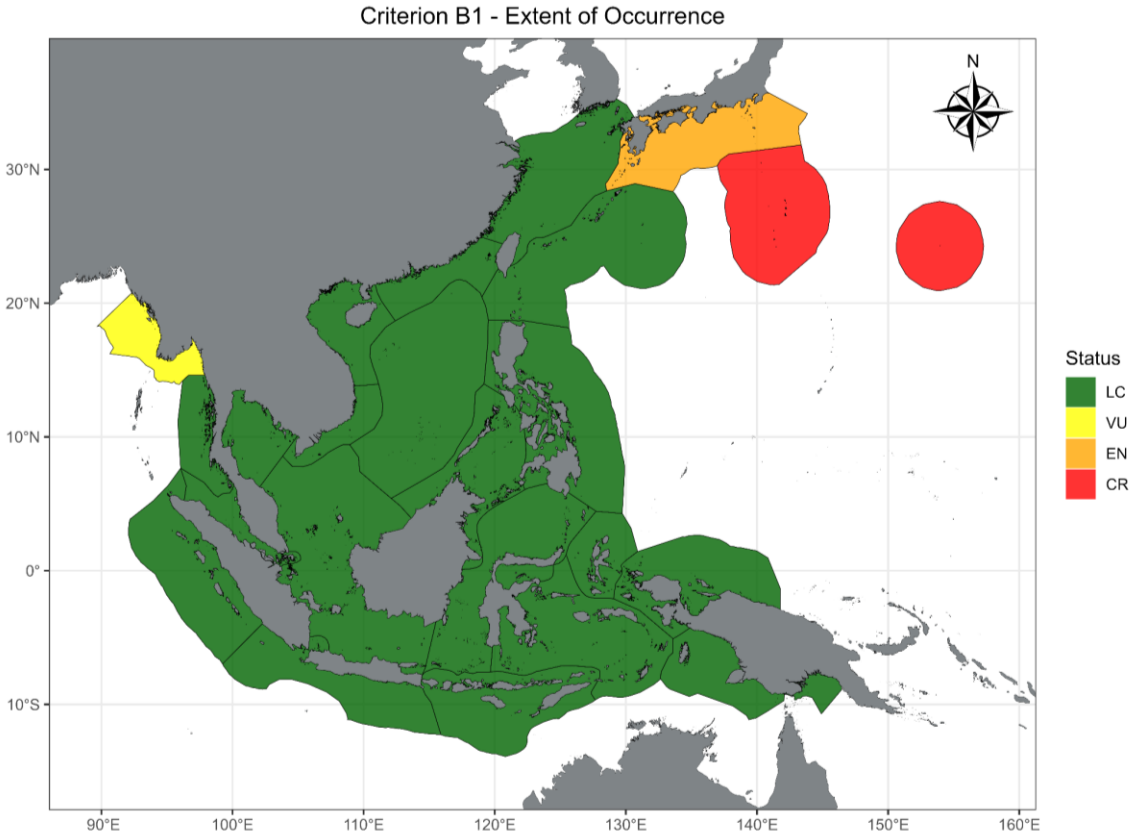


Figure 7 | Risk status under sub-criterion B1, based on the extent of occurrence (EOO) of coral reefs within each ecoregion evaluated.

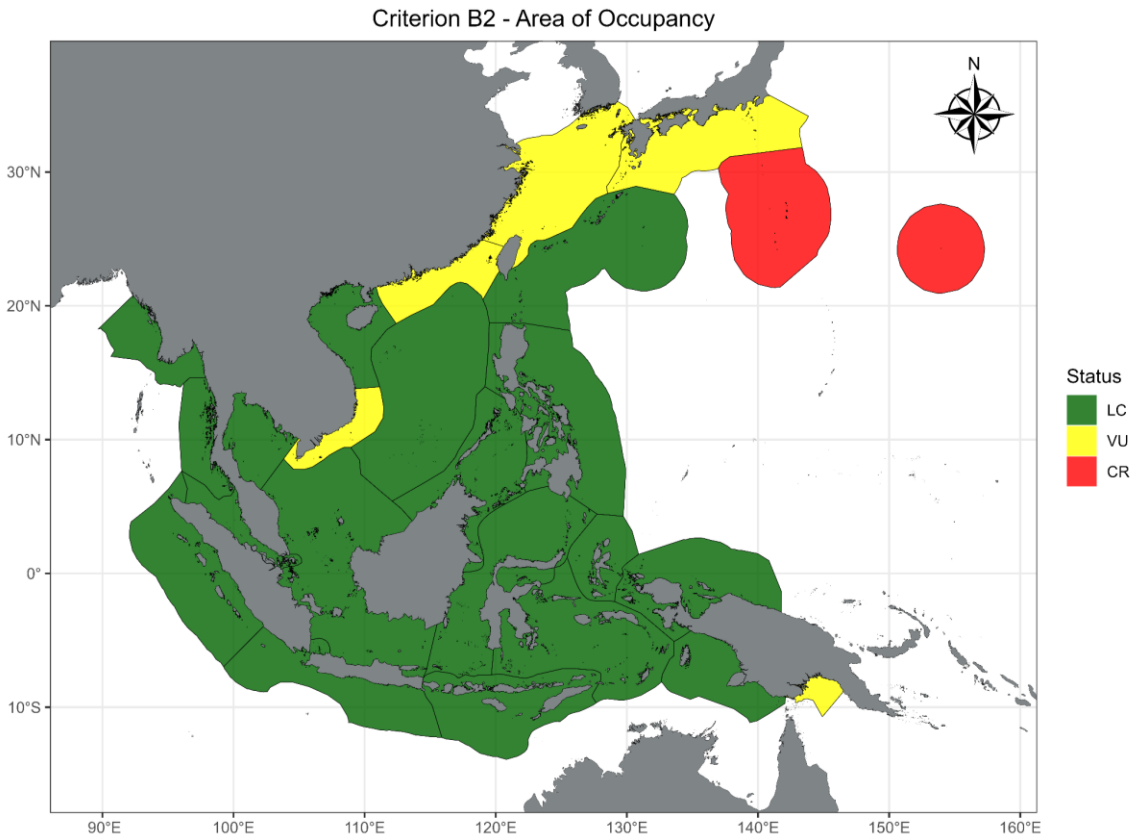


Figure 8 | Risk status under sub-criterion B2, based on the area of occupancy (AOO) of coral reefs within each ecoregion evaluated.

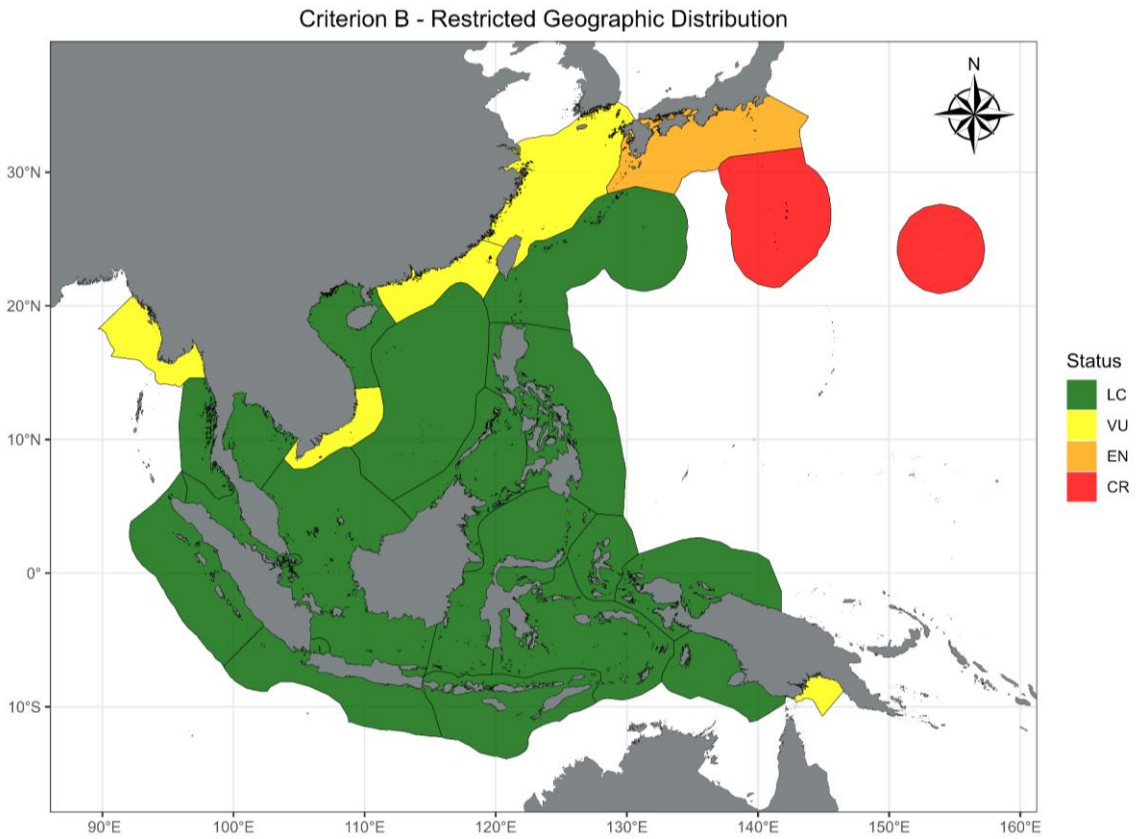


Figure 9 | Risk status under Criterion B (restricted geographic distribution) taken as the higher risk status of sub-criteria B1 and B2.

Criterion C: Environmental Degradation

Based on historical and projected thermal stress, **all** of the **25** ecoregions assessed are classified as **Critically Endangered** under Criterion C. No other risk classes are assigned under criterion C, due to the overwhelming influence of projected ocean warming assessed under the C2 criterion.

Under sub-criterion C1, which is based on observed Degree Heating Weeks (DHW) over the past 50 years, 16 ecoregions are assessed as threatened (**five Critically Endangered**, **five Endangered** and **six Vulnerable**), while **nine** ecoregions are categorised in lower risk classes (**Least Concern** or **Near Threatened**). All ten ecoregions assessed as Critically Endangered or Endangered under C1 lie at the margins of the region, while most lower-risk ecoregions lie in the Coral Triangle and on the Sunda Shelf.

Projections of DHW assessed under criterion C2 returned a classification of Critically Endangered in all ecoregions across East Asia, highlighting the imminent risk of collapse of reef systems across the region.

Table 7 | Risk status of **East Asian** coral reef ecoregions under Criterion C, determined from estimated declines in abiotic conditions, specifically changes in extreme heat events.

Coral Reef Ecoregion	Risk Status under Criterion C1	Risk Status under Criterion C2
1 - Central Kuroshio Current	CR	CR
2 - East China Sea	CR	CR
3 - Northern Bay of Bengal - Myanmar	EN	CR
4 - Andaman Sea Coral Coast	VU	CR
5 - Western Sumatra	LC	CR
6 - Gulf of Tonkin	EN	CR
7 - Southern China	CR	CR
8 - South China Sea Oceanic Islands	NT	CR
9 - Gulf of Thailand	VU	CR
10 - Southern Vietnam	VU	CR
11 - Sunda Shelf/Java Sea	NT	CR
12 - Malacca Strait	NT	CR
13 - Southern Java	EN	CR
14 - South Kuroshio	EN	CR
15 - Ogasawara Islands	CR	CR
16 - Palawan/North Borneo	VU	CR
17 - Eastern Philippines	NT	CR
18 - Sulawesi Sea/Makassar Strait	NT	CR
19 - Halmahera	NT	CR
20 - Papua	LC	CR
21 - Banda Sea	VU	CR
22 - Lesser Sunda	LC	CR
23 - Northeast Sulawesi	VU	CR
24 - Gulf of Papua	CR	CR
25 - Arafura Sea	EN	CR

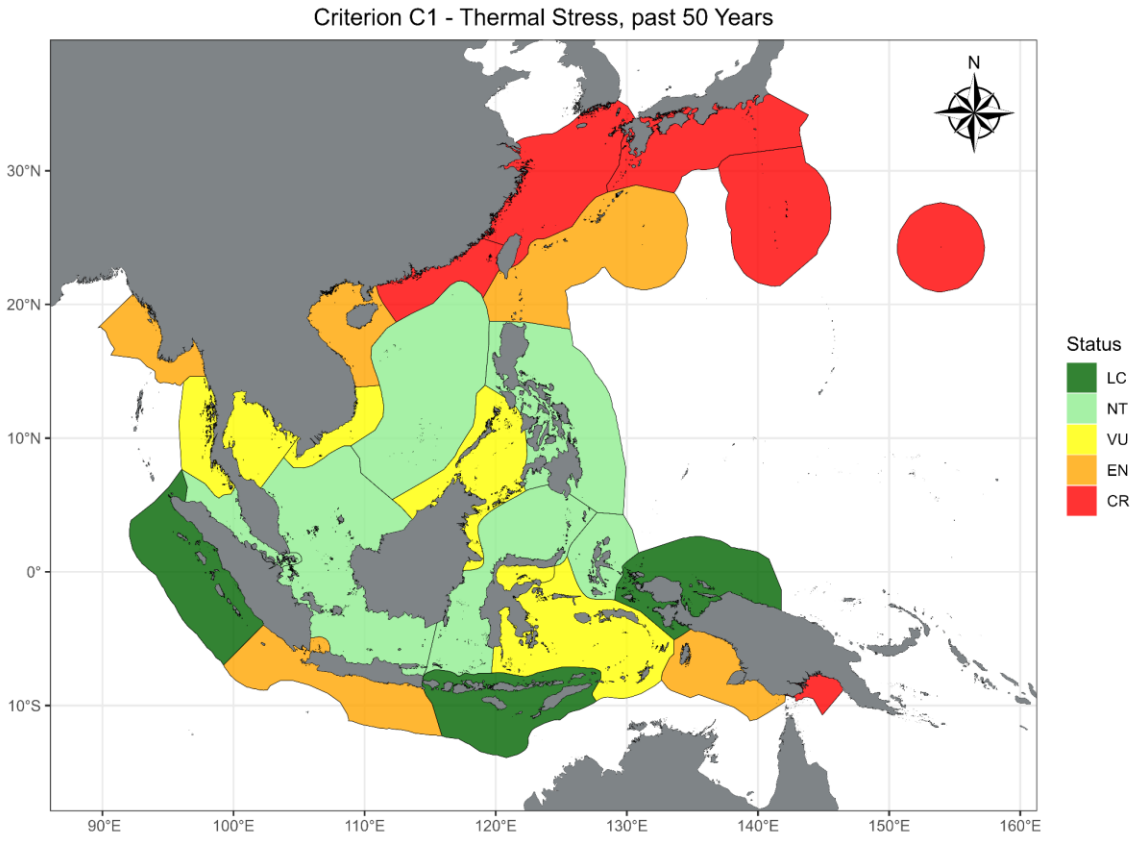


Figure 10 | Risk status under sub-criterion C1, based on observed thermal stress over the past 50 years (1975–2025).

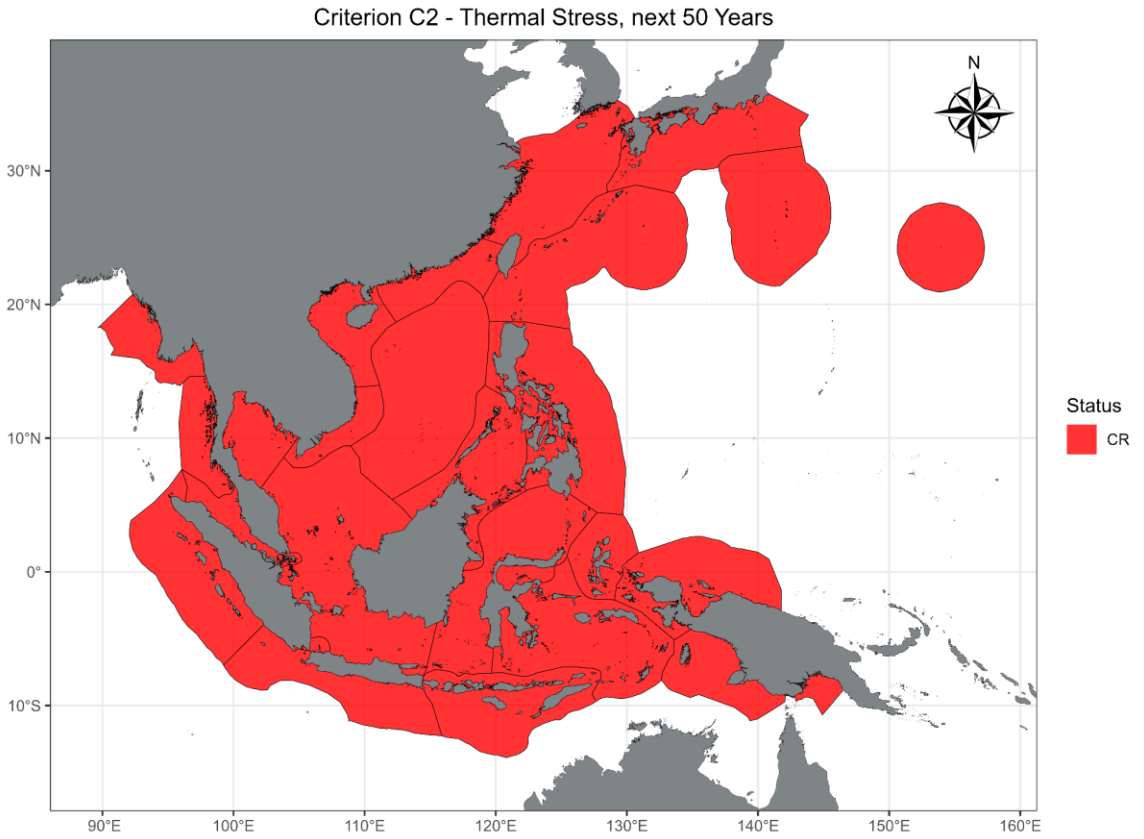


Figure 11 | Risk status under sub-criterion C2, based on forecasted thermal stress over the next 50 years (2026–2075).

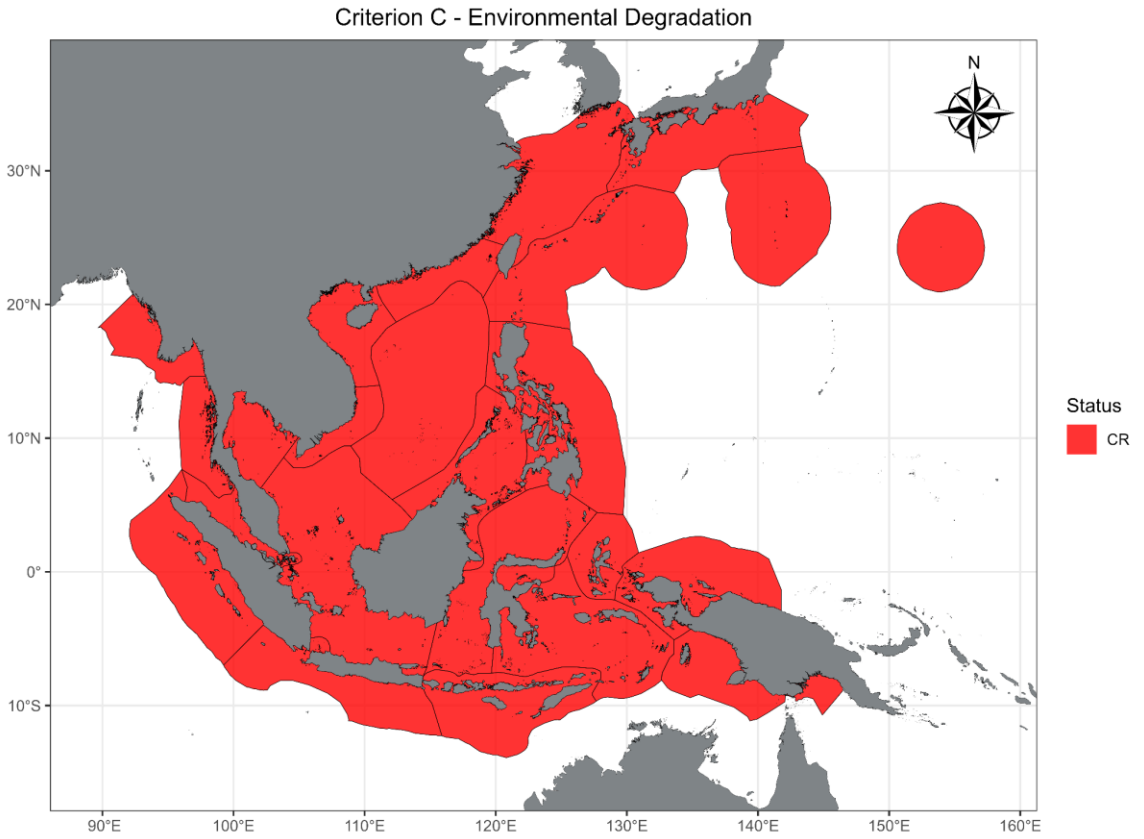


Figure 12 | Risk status under Criterion C (environmental degradation), taken as the highest risk status across the chronic and acute thermal stress pathways and both sub-criteria.

Criterion D: Disruption of biotic processes or interactions

Criterion D could only be assessed for 21 of the 25 ecoregions. Of those, **18** met the threshold for threatened status (**Vulnerable** or **Endangered**), 2 are **Near Threatened** while 1 was assessed as **Least Concern**. The remaining 4 ecoregions are classified as **Data Deficient**. Available data on herbivore and predator density suggests moderate to severe disruption of trophic interactions in several ecoregions, indicating that the largest biotic disruption is driven by the depletion of key fish groups.

Table 8 | Risk status of **East Asian** coral reef ecoregions under Criterion D, determined from estimated historical declines in up to four critical biotic components. The overall status is determined through a step-wise approach considering the risk of each indicator in ecological order from left to right. 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. Overall risk is considered DD if hard coral risk is DD.

Coral Reef Ecoregion	Hard corals	Algae-coral ratio	Parrotfish	Groupers	Overall
1 - Central Kuroshio Current	LC	DD	EN	CR	VU
2 - East China Sea	NT	LC	EN	VU (VU-EN)	VU

Coral Reef Ecoregion	Hard corals	Algae-coral ratio	Parrotfish	Groupers	Overall
3 - Northern Bay of Bengal - Myanmar	VU	DD	LC	NT	VU
4 - Andaman Sea Coral Coast	LC	LC	VU (NT-VU)	EN	VU
5 - Western Sumatra	LC	DD	NT	EN	VU
6 - Gulf of Tonkin	NT	LC	VU (NT-VU)	LC (LC-NT)	VU
7 - Southern China	NT (LC-NT)	LC	CR (EN-CR)	CR	EN
8 - South China Sea Oceanic Islands	DD	DD	DD	DD	DD
9 - Gulf of Thailand	LC	LC	VU	VU	VU
10 - Southern Vietnam	EN	VU	NT	EN	EN
11 - Sunda Shelf/Java Sea	LC	LC	NT	NT	NT
12 - Malacca Strait	NT	LC	EN	NT	VU
13 - Southern Java	VU (NT-VU)	DD	LC	VU	VU
14 - South Kuroshio	VU	NT	EN	EN	EN
15 - Ogasawara Islands	LC	DD	LC	LC	LC
16 - Palawan/North Borneo	NT	LC	VU	EN (VU-EN)	EN
17 - Eastern Philippines	NT	LC	NT	NT	NT
18 - Sulawesi Sea/Makassar Strait	LC	DD	NT	VU	VU
19 - Halmahera	DD	DD	DD	DD	DD
20 - Papua	NT	DD	EN	CR	EN
21 - Banda Sea	NT	DD	CR	CR	EN
22 - Lesser Sunda	NT	LC	EN	CR	EN
23 - Northeast Sulawesi	LC	DD	EN	EN	VU
24 - Gulf of Papua	DD	DD	EN	CO	DD
25 - Arafura Sea	DD	DD	DD	DD	DD

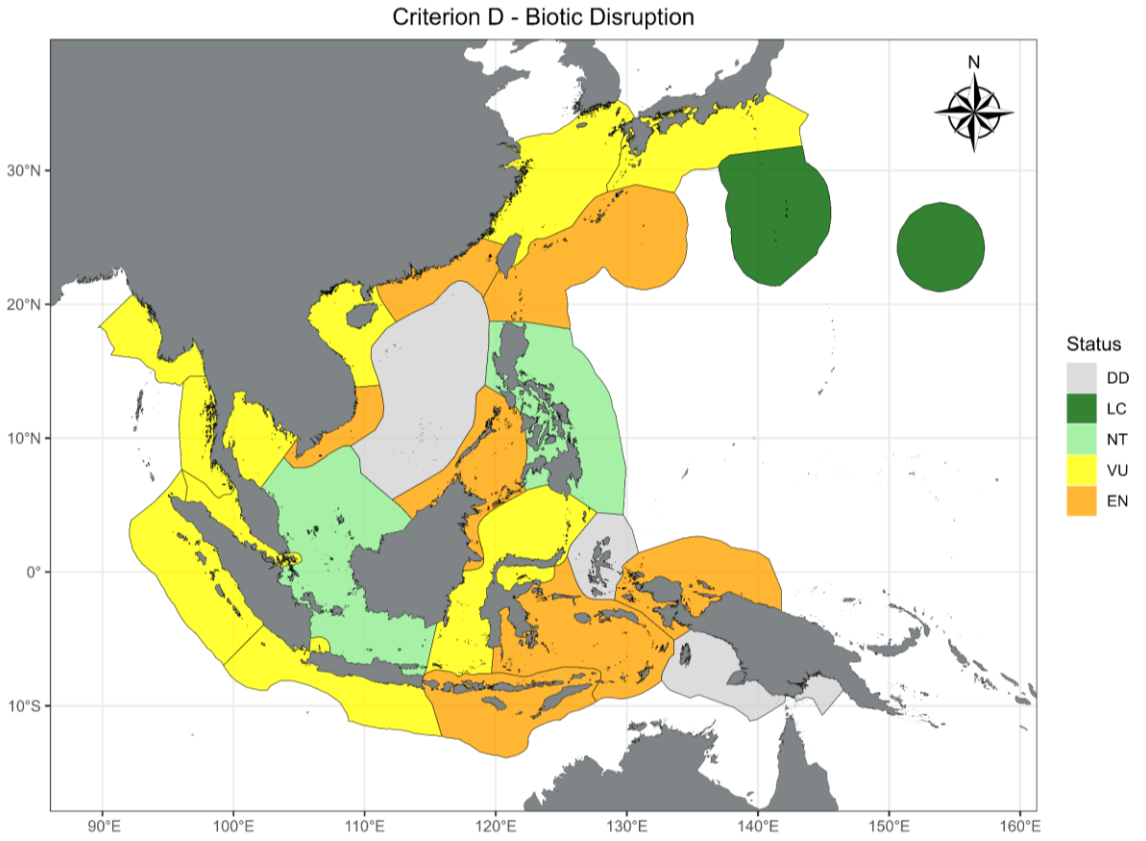


Figure 13 | Overall risk status under Criterion D (biotic disruption) obtained from the stepwise combination of the four biotic indicators. Ecoregions without an assessed hard coral cover trend are considered Data Deficient, as hard coral cover is the foundational indicator to assess this criterion.

4. Conclusion and recommendations

East Asian coral reefs face a high risk of collapse due to compounding local and global pressures. While reefs in East Asia are widely distributed, have remarkably stable hard coral cover (Chan et al., 2023; Kimura et al., 2022), and have shown relatively strong resilience to bleaching in parts of the Coral Triangle (Kimura et al., 2026b), projected future warming combined with depletion of fish stocks is highly likely to drive several reef systems towards the brink of collapse.

In this assessment, we analyzed the state of coral reefs in 25 marine ecoregions against Criteria A, B, C and D of the IUCN Red List of Ecosystems. Loss of coral reef habitat over the past 50 years was limited across most of the region. In fact, only two of the 23 ecoregions assessed under Criterion A reached a threatened category (Southern Vietnam and South China Sea Oceanic Islands), both of which have a long history of habitat loss. Given the wide distribution of coral reefs across East Asia, most ecoregions assessed are not considered to be threatened under Criterion B, with the exception of comparatively small and/or isolated reef systems such as the Ogasawara Islands. In contrast, the results under the remaining two criteria are markedly different. Under Criterion C, 16 ecoregions are already threatened

based on observed heat stress (C1), while all ecoregions are projected to approach the collapse thresholds within the coming decades (C2) and are therefore assessed as Critically Endangered. Furthermore, depleted parrotfish and grouper populations drove 18 of the 21 ecoregions assessed under Criterion D into threatened categories. Overall, based on historical declines and present conditions alone, 22 ecoregions are assessed as threatened, with five of them Critically Endangered.

The overwhelming influence of warming oceans (assessed under Criterion C) on the overall results underscores the urgency for rapid global climate mitigation. Only substantial reductions in greenhouse gas emissions can limit further increases in temperatures and in the frequency of marine heatwaves (Hughes et al., 2017; IPCC, 2022). While hard coral cover remains stable (Chan et al., 2023; Kimura et al., 2026b), shifts in coral assemblages may be masked (Chan et al., 2024), and fish assemblages maintaining crucial ecosystem functions such as herbivory and predation are already heavily depleted (Lavides et al., 2016). It is therefore essential to move towards more sustainable fishing practices to restore key reef ecosystem functions, as regional and national management programs can still influence local outcomes (Bellwood et al., 2004). Conservation actions should prioritize areas with higher resilience and lower projected thermal stress (Beyer et al., 2018; Sully et al., 2022). We also call for increased support and funding for coral reef monitoring, and urge potential collaborators and data contributors to close the substantial knowledge gaps that remain in ecoregions such as the Arafura Sea, the Gulf of Papua, Halmahera and the South China Sea Oceanic Islands. Ultimately, improving monitoring frameworks and expanding effective protection under the Kunming–Montreal Global Biodiversity Framework (CBD, 2022) would promote these actions regionally and help preserve East Asian coral reefs for future generations.

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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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10.Annex

10.1. Boundary definitions

The set of East Asian coral reef ecoregions assessed was selected based on the Marine Ecoregions of the World (MEOW) framework (Spalding et al., 2007). Of the 28 MEOW ecoregions initially considered within East Asia, 25 were retained as units of assessment. The remaining three (Sea of Japan, Yellow Sea and Northeastern Honshu) were excluded as they do not contain 'true' accreting (Type A) or marginal (Type B) coral reefs. Ecoregion boundaries were refined with inputs from regional and national coordinators of the East Asian GCRMN node during a series of regional workshops. In the Central Kuroshio Current, all sites north of 31°N were excluded as non-reefal, since corals there grow on rocky substrata rather than on accreting reefs. The Northern Bay of Bengal ecoregion was cut at the Myanmar–Bangladesh border, and its remaining part is assessed in the South Asia regional RLE report. Finally, the Andaman and Nicobar Islands ecoregion was assessed in the South Asia regional RLE report.

Table 9 | Summary of units of assessment within East Asia, including the ecoregions assessed, the countries or territories included, the estimated coral reef area, as well as the ecological and biogeographic characteristics supporting their delineation as distinct units of assessment. Coral reef

areas reported in this table were calculated from the regionally verified version of the UNEP-WCMC Millennium Coral Reef layer used in this assessment (see Criterion B).

Ecoregion	Country/ Territory	Coral Reef Area (km^2)	Boundary Description	Justification
1 - Central Kuroshio Current	Japan	39.9	Extends between 28.34°N and 35.81°N, 128.44°E and 143.85°E. Following feedback from GCRMN East Asia national coordinators, all sites north of 31°N were excluded as they are considered non-reefal where corals grow on rocky substrata.	Thermal moderation & connectivity through Kuroshio Current; cold-water stress; Transition to rocky/non-reefal communities northwards (northern limit of reef development)
2 - East China Sea	China, Republic of Korea, Taiwan, Japan	102.2	Extends between 22.75°N and 35.31°N, 118.85°E and 130.65°E.	Marginal reefs (Taiwan) and rocky, soft coral dominated reefs (Jeju, Ribas-Deulofeu et al., 2016, 2023); High proportion of non-reef-building coral communities and macroalgae; Tropicalisation (Yamano et al., 2011)
3 - Northern Bay of Bengal - Myanmar	Myanmar	372.3	Extends between 13.92°N and 20.85°N, 89.67°E and 97.92°E. For this assessment, the ecoregion was cut at its north-western edge, at the border along the coast between Myanmar and Bangladesh. The remaining part of this ecoregion is assessed in the regional RLE report of South Asia.	Reefs exist under conditions of high turbidity originating from large quantities of terrigenous sediment transported by river output and high resuspension rate (Ramaswamy et al, 2004). Furthermore, reefs in this ecoregion face chronic high fishing pressure from predominantly artisanal fisheries (Akester, 2019).
4 - Andaman Sea coral Coast	Myanmar, Thailand	137.6	Extends between 5.52°N and 14.62°N, 95.83°E and 100.13°E.	A large proportion of reefs here are intertidal, and located in areas with very large tidal ranges. In addition, reefs are also influenced by the Indian Ocean Dipole, which further modifies tidal windows during active years.
5 - Western Sumatra	Indonesia	1,507.6	Extends between 6.98°S and 7.67°N, 92.06°E and 102.31°E. Mainly located along the western coast of Sumatra.	The Indian Ocean Dipole is a major driver for upwelling, temperature, and acute disturbance for reefs in this ecoregion. The northernmost reefs in this ecoregion (around Aceh) are uniquely exposed to the Andaman Sea, the Strait of Malacca, and the Indian Ocean.
6 - Gulf of Tonkin	Vietnam, China	248.6	Extends between 13.81°N and 21.92°N, 105.62°E and 112.41°E.	This ecoregion is generally shallow (50-60 m), with wide annual temperature range, and experiences high volumes of river discharge, introducing sediment load and swings in salinity. Such conditions favour relatively stress-tolerant coral taxa (Latypov, 2003).
7 - Southern China	China, Taiwan	178.2	Extends between 18.68°N and 24.99°N, 110.88°E and 120.61°E. Following feedback from GCRMN East Asia national coordinators, eight records from the Western Fangji Island (China) were excluded as non-reefal	Reefs occur sporadically at several points along the mainland, and are concentrated around Hainan Island. Reefs in this ecoregion are exposed to a very wide range of turbidity conditions (Veron et al., 2015), and are threatened by a broad range of both natural disturbances, and

Ecoregion	Country/ Territory	Coral Reef Area (km^2)	Boundary Description	Justification
			environments where corals grow on rocky substrata.	intense development-driven anthropogenic stressors.
8 - South China Sea Oceanic Islands	China, Malaysia, Vietnam, Philippines	3,289.0	Extends between 5.41°N and 21.76°N, 108.94°E and 119.52°E.	Reefs are predominantly associated with offshore archipelagic and seamount complexes, with very clear waters (Veron et al., 2015), and are threatened by intensive fisheries activity.
9 - Gulf of Thailand	Thailand, Cambodia, Vietnam	144.6	Extends between 6.25°N and 13.61°N, 99.14°E and 104.97°E.	Some reefs experience high turbidity via terrigenous sediment, upwelling-driven nutrient influx, and large variations in salinity, favouring assemblages of stress-tolerant coral taxa. Reef quality is also noted to increase from nearshore to offshore sites.
10 - Southern Vietnam	Vietnam	103.9	Extends between 7.77°N and 13.95°N, 103.82°E and 111.47°E.	Mainland and offshore reefs (Con Dao, Nha Trang)
11 - Sunda Shelf/ Java Sea	Malaysia, Indonesia	2,147.7	Extends between 8.36°S and 9.42°N, 102.07°E and 115.52°E.	Reefs are characterized by species-rich coral assemblages (Huang et al., 2015), and are typically structurally complex; algal abundance is high, but macroalgal abundance is very low (< 1%) (Kennedy et al., 2020). Fish diversity is also very high, with relatively intact trophic structures, as shown by presence of top predators like sharks (Afiq-Firdaus et al., 2021).
12 - Malacca Strait	Malaysia, Indonesia, Singapore	164.9	Extends between 0.22°N and 7.67°N, 96.04°E and 105.21°E. The region occupies the narrow strait between the west coast of Peninsular Malaysia and the North-East coast of Sumatra (Spalding et al., 2007).	High turbidity due to sediment input from large rivers and land reclamation; Vertical compression of reefs with shallow lower limit of accretion; Turbidity- and stress-tolerant coral taxa (Porites spp., Merulinidae); Strong currents
13 - Southern Java	Indonesia	196.4	Extends between 12.27°S and 3.97°S, 99.24°E and 115.90°E.	Reefs experience both heat and cold stress, with temperatures driven by both Indian Ocean Dipole and ENSO events (Watanabe et al., 2026). Contains reefs ranging from nearshore to offshore, with varying degrees of exposure to a major urban center (Jakarta).
14 - South Kuroshio	Japan, Taiwan, Philippines	906.0	Extends between 18.15°N and 28.94°N, 119.02°E and 134.66°E.	The Kuroshio Current is a major driver, serving as a dispersal corridor, facilitating the transport of larval fishes, corals, and other invertebrates from the northwestern Philippines and eastern Taiwan to higher-latitude regions (Saito & Iguchi, 2025). This process sustains high biodiversity and enables coral reef development even at higher latitudes, such as

Ecoregion	Country/ Territory	Coral Reef Area (km^2)	Boundary Description	Justification
				around the Amami Islands (Reimer et al., 2019).
15 - Ogasawara Islands	Japan	0.4	Extends between 20.93°N and 31.83°N, 136.97°E and 157.30°E.	Fringing reefs across around 30 sparsely dispersed oceanic islands (high isolation)
16 - Palawan/ North Borneo	Malaysia, Brunei Darussalam, Philippines	7,926.0	Extends between 0.09°N and 13.96°N, 112.10°E and 122.39°E	High reef-fish diversity and endemism; geologically distinct from the rest of the Philippine archipelago
17 - Eastern Philippines	Philippines	4,862.3	Extends between 4.28°N and 18.74°N, 119.19°E and 129.92°E.	High diversity of reef-building corals; The Central Philippines holds the highest diversity in marine invertebrates and shore fishes
18 - Sulawesi Sea/ Makassar Strait	Indonesia, Philippines, Malaysia	3,004.6	Extends between 7.80°S and 6.49°N, 114.48°E and 127.73°E.	Indonesian Throughflow drives larval connectivity
19 - Halmahera	Indonesia	542.3	Extends between 2.10°S and 4.44°N, 125.44°E and 130.90°E.	Highly complex habitats with leeward reefs and sites open to Pacific swells, several volcanic islands and underwater seamounts (Green & Mous, 2008; Huffard et al., 2012). Upwelling driven by the Indonesian Throughflow contributes to high biodiversity and mitigates temperature stress (Huffard et al., 2012). High diversity and endemicity of fish and coral taxa, highestcoral richness per unit area (DeVantier & Turak, 2017).
20 - Papua	Indonesia, Papua New Guinea	2,064.3	Extends between 5.08°S and 2.66°N, 129.06°E and 141.78°E.	High sea surface temperature variability (up to 16 °C, Huffard et al., 2012). Transitional zone between the Pacific Ocean and the Indonesian seas (Green & Mous, 2008). Highest fish diversity in the Coral Triangle (~1700 spp.; Allen, 2008), with very diverse coral communities (Veron et al., 2015).
21 - Banda Sea	Indonesia	5,629.5	Extends between 9.67°S and 1.20°N, 119.67°E and 133.60°E.	High coral diversity and endemicity
22 - Lesser Sunda	Indonesia, Timor Leste	949.6	Extends between 13.90°S and 7.12°S, 114.34°E and 128.01°E.	High diversity of coral and fish taxa, and high endemicity of coral taxa.
23 - Northeast Sulawesi	Indonesia	286.6	Extends between 1.43°S and 0.55°N, 120.00°E and 124.48°E.	Very high coral species richness (Veron et al., 2015) and high fish species richness (1577 spp.; Allen, 2008). The environment of the inner bay supports high larval connectivity across reefs (Green & Mous, 2008).
24 - Gulf of Papua	Papua New Guinea	385.2	Extends between 10.71°S and 7.39°S, 142.08°E and 146.46°E.	Low-reef-development setting bordered by major reef systems on either side. Coral communities are developed on hard substrates and

Ecoregion	Country/ Territory	Coral Reef Area (km^2)	Boundary Description	Justification
				rubble banks away from the main influence of the Fly River, and waters are mostly clear offshore but turbid nearshore (Veron et al., 2015).
25 - Arafura Sea	Indonesia, Papua New Guinea	430.2	Extends between 11.15°S and 4.27°S, 132.66°E and 142.08°E.	High turbidity because of sediment inputs from multiple rivers. Biogeographic link between Papua, Sulawesi and Australian faunas.

10.2. Methods

Data

Criteria A and D were assessed using in situ reef monitoring data compiled from various sources. The GCRMN East Asia dataset (Kimura et al., 2026b) constituted the primary component of the compiled dataset for both benthic and fish data. Assembled by the network's regional and national coordinators, it incorporates inputs from national monitoring programmes, university-based survey results, and non-governmental organisations spanning 14 countries and territories. Following regional expert advice, high-latitude non-reefal monitoring sites in Japan, South Korea and eight records from non-reefal sites in China were excluded. Surveys followed a wide variety of standard protocols of the contributing programmes and countries, including line and point intercept transects, photo-quadrats and timed swims for benthic cover, and underwater visual census along belt transects as well as timed swims for fish. All data retrieved from timed swims (i.e. Spot-Check Method) stem from Japan and was obtained by surveying a fixed area to provide quantitative data, covering the Central Kuroshio Current, South Kuroshio and Ogasawara Islands ecoregions.

For benthic data, we also added data compiled from the MERMAID data portal (accessed through the *mermaid* R package, Version 1.3.1, Gelfand 2026) and from an additional data source from Indonesia (Yayasan Konservasi Alam Nusantara, YKAN), which helped improve the spatial coverage in otherwise underrepresented yet important regions of East Asia such as Indonesia and the Philippines. The YKAN dataset covered reef sites around Kofiau and Misool in the Raja Ampat region, and was standardized to the GCRMN format for this assessment. The percent cover of hard coral and macroalgae were the most commonly recorded benthic categories at each individual transect. Following feedback from GCRMN East Asia regional and national coordinators, we excluded all records from South Korea as well as some higher-latitude sites from Japan and along the coast of China, as these are considered non-reefal since corals grow on rocky substrata rather than on accreting coral reefs. After standardisation, the combined benthic dataset comprised 73,742 benthic cover observations between 1983 and 2025, of which 42,147 were hard coral records, from 4,030 monitoring sites distributed across 23 of the 25 ecoregions assessed (Table 10).

The GCRMN reef fish dataset was supplemented with data from the Reef Life Survey (Edgar & Stuart-Smith, 2014), hosted by the Australian Integrated Marine Observing System (IMOS), and from the MERMAID data portal. Since size information was not always available in the GCRMN East Asia root dataset, we worked with abundance records. To ensure the comparability of these records obtained from different transect lengths, abundance values were standardized by the area sampled. The reef fish dataset consisted of obtained abundance records for the consumer groups used under Criterion D, namely parrotfishes (Scarinae) as a proxy for herbivory and groupers (Epinephelidae) as a proxy for piscivory on reef ecosystems. Where the taxonomic resolution allowed (in the MERMAID and Reef Life Survey records), the abundance of groupers only was analyzed. In the GCRMN dataset, we used the abundance of Serranidae instead of groupers given the lower taxonomic resolution of the dataset. Consequently, it is important to note that in some countries (Malaysia, Japan) this category represented groupers only, while in others (Cambodia, Indonesia, Myanmar, Taiwan, Thailand, Vietnam, Philippines & Singapore) it represented all Serranidae combined. Serranidae in the broad sense also used to include non-piscivorous anthias, hence the substitution of Epinephelidae with the broader Serranidae can inflate counts where Serranidae was recorded in the broad sense. The records considered for these analyses span between 1983 and 2025. Ultimately, the final fish dataset comprised 20,578 parrotfish and grouper abundance records from 2,009 monitoring sites distributed across 22 of the 25 ecoregions assessed (Table 13).

Study sites located within 150 m of each other were pooled into a single analytical unit (as they arguably represent the same monitoring location), which allowed to limit fine-scale pseudoreplication. In order to select an appropriate pooling distance, we performed a sensitivity sweep across 100–250 in 50 m steps and selected 150 m as this allowed us to pool most co-located sites without averaging 'truly' different sites located further apart. Where multiple records (i.e. replicates, or in case of multiple surveys per year) existed for a site within this period, the **average across all surveys and years** was used. Hence, after averaging we obtained one indicator value per year for each site. Additional records (MERMAID & YKAN for benthic cover; MERMAID & RLS for fish) falling within 150 m of a GCRMN site were removed as duplicates, unless they contributed a different survey year compared to the co-located GCRMN records. These methodological steps ensured also that sites do not enter the analysis twice while being considered different units, which would erroneously inflate site count.

Reef typology

We used the IUCN Global Ecosystem Typology (GET) to ensure a consistent and globally aligned definition of coral reef ecosystems.

Within the GET, true photic coral reefs are classified under the ecosystem functional group 'M1.3 Photic Coral Reefs'. These ecosystems are characterized 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. In East Asia, marginal reefs occur mainly towards the higher latitude margins of the region, for example in eastern and northern Taiwan (Ribas-Deulofeu et al., 2016). 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). In East Asia, these rocky reef systems occur at high latitude, for example around Jeju Island in South Korea as well as mainland Japan. These non-accreting reefs were excluded by retaining only reef monitoring sites located South of 31°N latitude. Finally, we also excluded 8 records from monitoring sites on Type C reefs from the Western Fangji Island in China. Care was taken not to exclude degraded coral reefs that may superficially resemble rocky or other reef systems, as these represent important expressions of coral reef degradation and are central to assessing collapse risk.

The occurrence and distribution of selected reef types within the region were delineated using **a combination of expert judgement (via input from the regional coordinators of the GCRMN East Asia node), field observations, 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). Sub-Criteria A2a, A2b or A3, requiring assessment into the future, 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. Current hard coral cover at any given site was calculated as the mean of all observations recorded from 2020 onwards. This was calculated after averaging all transect replicates to obtain a single value per site and year. Sites surveyed in only one recent year were retained, since this analysis requires a single current estimate rather than a time series.

Each reef site was classified as either a functioning, net-accreting reef site or a degraded site, based on a threshold of approximately **10%** 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). The 10% threshold is the same as the one used in the Western

Indian Ocean assessment (Obura et al., 2022), yet higher than the 5% used in most other regions evaluated in the present RLE assessment. The reasoning behind the choice of this threshold was the generally resilient and high hard coral cover values found across East Asia, even in recent decades and with sustained heat stress.

A sensitivity analysis was conducted across a range of thresholds (1–10%) to assess how results varied (Supplementary Materials, Fig. S3). 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. No sites were excluded on the grounds of already being degraded in 1975, as we have no site-level benthic cover data from East Asia from that period. In addition, to account for potential data gaps, **53** sites known to have collapsed or been permanently lost due to anthropogenic or environmental pressures, such as cyclones, dredging, sedimentation, port development, or severe bleaching, were also included, even if they are no longer part of ongoing monitoring programs (no data from 2020 onwards). These were identified as sites that were last surveyed before 2016 and whose final recorded hard coral cover was less than 5%. The minimum hard coral cover threshold is deliberately stricter than the 10% threshold outlined earlier, to ensure that only unambiguously collapsed sites are considered as such. The list of candidate sites was verified with our network of regional coordinators, and sites where monitoring had simply been discontinued, rather than the reef having collapsed, were removed. In addition, three sites in Singapore (Sultan Shoal North, Sultan Shoal South and Pulau Semakau Northeast) which were lost due to land reclamation within the assessment window were added as dummy sites to the dataset for criterion A with a recent hard coral cover record of 0%. The monitoring series of these collapsed sites ends before 2020 and would otherwise have been excluded from the analysis, thus the inclusion of these collapsed sites ensures that historical coral reef area losses were adequately captured.

Current (and additional degraded) monitoring sites were mapped against the spatial extent of coral reefs to determine the coverage and representativeness of existing monitoring efforts. Hard coral cover data was available for 23 of the 25 ecoregions assessed for East Asia. 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). Both measures were derived from the same reef extent layer and the same grid used under Criterion B, so that both monitoring coverage and reef extent are expressed on a common basis. 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)**. In total, **2** ecoregions were classified as Data Deficient under Criterion A (Gulf of Papua & Arafura Sea), as there was no benthic survey data available since 2020.

Table 10 | A summary of the number of sites with hard coral cover data used to assess Criterion A (2,794 benthic monitoring sites in total).

Ecoregion	Number of sites
1 - Central Kuroshio Current	43
2 - East China Sea	11
3 - Northern Bay of Bengal - Myanmar	28
4 - Andaman Sea Coral Coast	78
5 - Western Sumatra	49
6 - Gulf of Tonkin	25
7 - Southern China	39
8 - South China Sea Oceanic Islands	27
9 - Gulf of Thailand	143
10 - Southern Vietnam	53
11 - Sunda Shelf/ Java Sea	204
12 - Malacca Strait	42
13 - Southern Java	22
14 - South Kuroshio	454
15 - Ogasawara Islands	12
16 - Palawan/ North Borneo	292
17 - Eastern Philippines	267
18 - Sulawesi Sea/ Makassar Strait	171
19 - Halmahera	83
20 - Papua	41
21 - Banda Sea	442
22 - Lesser Sunda	239
23 - Northeast Sulawesi	29
24 - Gulf of Papua	-
25 - Arafura Sea	-
East Asia	**2,794**

Where data were adequate, risk categories were assigned by comparing the proportion of assessed sites in an ecoregion with current hard coral cover below 10% against the Red List

of Ecosystems thresholds for Criterion A1. The latter correspond to declines of >80% (Critically Endangered), 50–80% (Endangered), 30–50% (Vulnerable), 27–30% (Near Threatened), and <27% (Least Concern) (see Fig. 15).

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%

Figure 14 | IUCN Red List of Ecosystems threshold values and time frames for assessing reduction in geographic distribution under Criterion A.

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**:

(i) Sub-criterion B1: Extent of Occurrence (EOO) – the area within the outer boundary of the ecosystem's known distribution;

(ii) 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. Two satellite-derived global coral reef maps were considered: the **Millennium Coral Reef Mapping Project** layer curated by the **UNEP World Conservation Monitoring Centre (UNEP-WCMC)**, and the **Allen Coral Atlas (ACA)** global reef map. Both layers were interrogated by regional experts to determine the most suitable layer for each ecoregion. For East Asia, the UNEP-WCMC layer (WCMC008 Coral Reefs 2021, version 4.1) was retained as base layer across all ecoregions. Experts also identified areas where reef extent appeared to be over- or under-represented and incorporated localised corrections into the selected layer. These corrections were made in QGIS by editing the base layer, which ultimately yielded an updated polygon layer. In this process, reefs that were known to regional experts but absent from the global map were hand-digitised as lines and converted to polygons by buffering by 100 m on either side, giving a 200 m wide reef ribbon representing a proxy for the reef extent. In total, 33 such features were added, mainly located along the coasts of Peninsular Malaysia and north-eastern Borneo. The hand-digitised polygons were then merged with the edited layer, and tagged with their source to ensure the traceability of these additions. The merged layer was then clipped to the MEOW ecoregion boundaries to ensure that reef area is attributed to the correct ecoregion.

Local corrections to the reef layer used in this project based on feedback from regional coordinators were concentrated in three ecoregions. Along the west coast of Peninsular Malaysia, off Port Dickson, two non-reefal polygons were removed from the root UNEP-WCMC Millennium layer, while newly digitised reefs were added. In northern Borneo, off Kota Kinabalu and south of Tambisan Island, reefs absent from the Millennium layer were added, while other polygons were removed either because their mapped extent was demonstrably too large or because they had been erroneously digitised as reefs. Reefs at Beting Patinggi Ali (Luconia Shoals) off western Sarawak, and several submerged reefs off Kuantan on the east coast of Peninsular Malaysia, were newly digitised following Hanapiah et al., (2020). All other ecoregions retain the root layer without any changes. The final reef extent layer contains mapped coral reefs in 25 ecoregions, and reef area in each ecoregion was calculated from this refined layer (Table 9).

Once the validated coral reef extent layer was projected using the **EPSG:3832 (WGS 84 / PDC Mercator)** coordinate reference system, which allows the whole region to be handled in a single projection, the *makeEOO* function in the *redlistr* package in R (Version 2.0.0, Lee et al., 2019) 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 each ecoregion from the union of all reef polygons within it. 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 (Fig. 15). Ecoregions with EOO or AOO values within 10% of the VU thresholds were classified as Near Threatened (NT), corresponding to an EOO between 50,000 and 55,000 km2 and an AOO of 51 to 55 grid cells.

Finally, to formally assign the risk status under Criterion B1 or B2 for each ecoregion, regional experts provided information on observed or inferred declines to reefs, or the presence of current threats, such as ocean warming, pollution, coastal development and overfishing that were contributing risk to coral reefs.

Figure 15 | Thresholds and conditions for assessing ecosystems under Criterion B (restricted geographic distribution) of the IUCN Red List of Ecosystems, showing sub-criteria B1 (extent of occurrence), B2 (area of occupancy) and B3. Adapted from Bland et al. (2017).

Subcriterion	Measure of geographic distribution	CR	EN	VU
B1	Area of a minimum convex polygon (km²) 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 km² 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

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 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 heatwaves reduce the environmental suitability for reef-building corals through several pathways. A shift in disturbance regime increases the risk of large-scale coral mortality and affects the establishment and persistence of species (Elma et al., 2023; Mudge & Bruno, 2023). These changes can be associated with substantial declines in coral

abundance, reduced structural complexity, and lower carbonate accretion rates (Williams et al., 2019). 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 heatwaves 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**, characterized 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 et al., 2016; Liu et al., 2006; 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., 2006; Skirving et al., 2019). In addition, DHW has been widely used in recent studies assessing bleaching risk under climate change (Beyer et al., 2018; Bozec et al., 2025; Mellin et al., 2024; Obura et al., 2022), 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 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 two climate pathways: **SSP2–4.5** and **SSP3–7.0**. The dataset did not include projections corresponding to the Paris Agreement pathway (SSP1–1.9; approximately 1.5–2°C warming by 2100), which has been considered increasingly unrealistic given current global emissions trajectories (Tagomori et al., 2026). All 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 the only scenarios evaluated.

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.

Because the East Asian region spans both hemispheres, the seasonal maximum was not extracted over a single, region-wide window. Reefs located in the north of the equator reach their thermal maximum in August–September (within a single calendar year), whereas reefs south of the equator reach it in December–March (straddling two calendar years). The

seasonal maximum was consequently extracted over two windows, namely a January–December window for reefs with a boreal season, and a July–June window for reefs with an equatorial season. In each case the window contained the hottest summer months of the corresponding season (August–September and January–March respectively), to ensure that truncated seasons at the start and end of the time series were dropped. To ensure comparable year labels between the two windows, each July–June season was labelled with the calendar year in which it began (e.g. December 2024–March 2025, the 2024/25 bleaching season, was assigned to 2024), consistent with the years used to define the ecoregion-specific DHW thresholds outlined below.

For both the observed (C1) and projected data (C2), the window was assigned at the ecoregion level by defining a list of ecoregions with an equatorial season (Arafura Sea, Banda Sea, Gulf of Papua, Halmahera, Lesser Sunda, Papua, Southern Java, Sulawesi Sea/Makassar Strait and Sunda Shelf/Java Sea). All remaining ecoregions were assigned the boreal window. We acknowledge that four of the ecoregions treated as equatorial straddle the equator and have no single dominant thermal season (Halmahera, Sulawesi Sea/Makassar Strait, Papua, and Sunda Shelf/Java Sea). Their assignment to the equatorial window was based on expert judgement, and reefs at the northern margin of these ecoregions were consequently evaluated on a window that may not correspond exactly with their local thermal peak.

This produced an annual time series of maximum DHW for each reef pixel spanning historical and future assessment periods. Reef pixels for which no valid seasonal maximum could be computed were excluded from the analysis.

Thresholds

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

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

DHW thresholds corresponding to severe bleaching events (chronic pathway) and severe mortality events (pulse pathway) for each ecoregion were informed by historical observations of coral reef responses to marine heatwaves, specifically the levels of thermal stress associated with widespread bleaching and coral mortality. These thresholds were not treated as fixed, as the DHW level required to trigger a given bleaching response is expected

to change over time. For example, in the 1980s and 90s, relatively lower DHW values may have resulted in severe bleaching and mortality (Hoegh-Guldberg, 1999), whereas coral communities today (or in the future) may be altered or acclimated, potentially requiring higher DHW values to trigger comparable responses (Heron et al., 2016; Pratchett et al., 2013; Sully et al., 2019). For sub-criterion 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 ecoregion level where locally relevant evidence supported this. To account for uncertainty in the exact level of heat stress that causes bleaching/mortality, two plausible DHW threshold values were applied for each pathway.

Ecoregion specific DHW thresholds were defined by matching records of thermal stress with documented bleaching responses within each ecoregion. In a first step, historical DHW time-series were plotted as violin plots (1985–2025) for a random selection of 1% of reef pixels. These figures enabled the simultaneous evaluation of both the magnitude of thermal stress events and the geographic spread across reefs within an ecoregion. Thermal stress events were visible as years in which the distribution of DHW values of reef pixels within an ecoregion shifts upwards. In parallel, we compiled records of coral bleaching and mortality from relevant scientific and grey literature sources, including regional and national monitoring reports and bleaching observations stored in the MERMAID database. The reported responses were classified by severity, separating limited from widespread bleaching and, where available, from widespread mortality.

In order to compare the reported responses of reefs to the abiotic conditions recorded, the literature based-values on the severity of bleaching and mortality were summarized in ecoregion-specific tables and related to reported DHW patterns within each ecoregion. Across most ecoregions, years with documented widespread bleaching coincided with peaks in the measured DHW, consistent with the threshold-setting approach described below.

The bleaching threshold for an ecoregion in a given time range was set at the DHW value separating years with a documented bleaching response from years without one (i.e. at or below the lowest DHW value associated with a documented bleaching response, and above the highest DHW value recorded in years without bleaching). In the case of multiple bleaching events within the same time range in an ecoregion, the threshold was re-evaluated against each of them and eventually adjusted where they were not consistent with a single value. Where no single value could separate the two sets of years across the time series because the DHW value associated with a reported response shifted over time, the time range was divided into periods and a separate threshold was assigned to each. The boundaries between these epochs were placed at the years where the shift in DHW threshold became evident. In total, 14 ecoregions carry more than one epoch over the observed period. For the other 11, a single threshold was applied throughout.

For several years, the DHW recorded at reef sites reached values well above the threshold. In these cases bleaching is assumed to have begun once accumulated stress reached the

threshold set based on earlier events. The stress accumulated beyond that point is assumed to contribute to more severe mortality rather than to a later onset of bleaching.

Similarly, mortality thresholds for the pulse pathway were set relative to the bleaching threshold of the same ecoregion and epoch. Where sufficient information about coral mortality associated could be retrieved from the literature, we used the DHW values retrieved through the analysis of the violin plots. Where the compiled information was insufficient, the mortality threshold was set at 2 DHW above the bleaching threshold. This methodological choice is based on the assumption that the additional accumulated thermal stress required to move from widespread bleaching to widespread mortality is consistent. For six ecoregions (Arafura Sea, Central Kuroshio Current, East China Sea, Gulf of Papua, Northern Bay of Bengal and Ogasawara Islands), we did not find sufficient evidence to derive ecoregion specific DHW thresholds. For example, for Central Kuroshio Current the available coral bleaching and mortality reports did not coincide consistently with peaks in the DHW record, while for East China Sea and Ogasawara Islands the reef-pixel record was too sparse to interpret. For these ecoregions, the default thresholds were set at 4 DHW for widespread bleaching and 8 DHW for severe mortality, which is consistent with the alert levels of the NOAA Coral Reef Watch.

Future DHW thresholds, which were used for the evaluation of sub-criterion C2, were based on the thresholds derived from observed bleaching records of the last observed epoch of each ecoregion. Under the moderate scenario, the most recent thresholds were carried forward unchanged from 2026, assuming no future change in response to thermal stress. Under the alternative scenario, bleaching thresholds were raised by 2 DHW and mortality thresholds by 4 DHW from 2026 onwards. Hence, the latter scenario assumes a greater extent of species filtering and thermal adaptation or acclimation.

The setting of ecoregion-specific DHW thresholds is limited by the availability of large-scale coral bleaching and mortality reports in the literature. Furthermore, at some sites in some years, there might have been widespread bleaching, yet there may have been no ongoing monitoring programs to document it.

With the thresholds derived from bleaching records, seven ecoregions were initially assessed as Least Concern under C1 (Banda Sea, Eastern Philippines, Lesser Sunda, Palawan/North Borneo, Papua, Sunda Shelf/Java Sea and Western Sumatra). Since the Least Concern status requires that an ecosystem unambiguously meets none of the quantitative criteria (IUCN, 2024), we re-examined these seven ecoregions. As bleaching may have gone unreported in some years, thresholds derived from the available records may overestimate the heat stress required to cause severe bleaching and mortality. We therefore repeated the C1 analysis with all thresholds lowered by 1 DHW and, after reviewing the compiled bleaching records of these seven ecoregions again, adopted the lower values as primary C1 thresholds. This applied to all epochs between 1985 and 2025 and to both pathways, so the gap between bleaching and mortality thresholds was unchanged. C2 thresholds were not lowered and remain based on literature records of widespread bleaching and mortality from the last observed epoch. Both the record-derived and the adopted DHW thresholds are listed in Tables 11 and 12.

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:

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

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

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 for 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) were characterized by bleaching events occurring at most once every 10–15 years, equivalent to approximately 2–3 events per 30-year period. This reflected 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 was 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 was the maximum number of severe mortality events within any 5-year window at the start of the satellite time series (1985/86–1990/91). For C2, the initial value was the maximum number of severe mortality events within any 5-year window during the decade immediately preceding 2026 (2016–2025).

Collapse thresholds

To complete the calculation of relative severity of decline, it is necessary to define a collapse threshold, when the frequency of damaging heatwaves creates a high likelihood of collapse. For coral reefs, collapse was defined by the near or complete loss of hard corals, corresponding to a **hard coral cover below 5%**. The same collapse thresholds were applied to both C1 and C2 because conceptually similar environmental conditions should lead to similar ecological outcomes regardless of when they occurred.

For the **chronic pathway**, the collapse threshold was 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 were considered insufficient to permit meaningful coral recovery between disturbances, and the cumulative, iterative mortality caused by several events drove 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 may not allow for full recovery, and could lead to substantial decline after multiple decades (Hughes et al., 2018). Annual severe bleaching was commonly cited when predicting future reef outlook (De Clippele et al., 2023; van Hooidonk et al., 2016; Zeng et al., 2025), but it was considered overly conservative as collapse may occur before conditions conducive to yearly bleaching would arrive (Bland et al., 2017; Obura et al., 2022).

For the **pulse pathway**, the collapse threshold was 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., (2022) 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, 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). Therefore, reefs may be more resilient to moderate clustering of events than previously assumed, and a higher frequency, specifically 2–3 extreme mortality events within a 5-year window, was required to reliably indicate conditions conducive to collapse.

Table 11 | Ecoregion-specific DHW thresholds representing thermal stress levels resulting in widespread bleaching for the chronic pathway. Thresholds can be time-varying to represent changing coral responses and increased warming. The thresholds apply to the seasonal maximum DHW series. The lower value of each future range is used for the primary scenario (threshold carried forward unchanged) and the upper value represents the alternative case (coral reef adaptation). Asterisks (*) indicate the seven ecoregions initially assessed as LC under C1, where the thresholds applied were 1 DHW below the record-derived values (in brackets), while C2 ranges remain unchanged.

Ecoregion	C1 – observed, past 50 years (1975–2025)		C2 – projected, future 50 years (2026–2075)	
	Timeframe	Widespread bleaching (DHW)	Timeframe	Widespread bleaching (DHW range)
1 - Central Kuroshio Current	1985–2025	4	2026–2075	4–6
2 - East China Sea	1985–2025	4	2026–2075	4–6
3 - Northern Bay of Bengal - Myanmar	1985–2025	4	2026–2075	4–6
4 - Andaman Sea Coral Coast	1985–2009 2010–2025	2 3	2026–2075	3–5
5 - Western Sumatra *	1985–2015 2016–2025	3 (4) 5 (6)	2026–2075	6–8
6 - Gulf of Tonkin	1985–2015 2016–2019 2020–2025	4 6 8	2026–2075	8–10
7 - Southern China	1985–2025	6	2026–2075	6–8
8 - South China Sea Oceanic Islands	1985–2019 2020–2025	4 6	2026–2075	6–8
9 - Gulf of Thailand	1985–1997 1998–2025	3.5 4	2026–2075	4–6
10 - Southern Vietnam	1985–1997 1998–2009 2010–2025	2 3 4	2026–2075	4–6
11 - Sunda Shelf/ Java Sea *	1985–2025	3 (4)	2026–2075	4–6
12 - Malacca Strait	1985–1999 2000–2025	2 3	2026–2075	3–5
13 - Southern Java	1985–2025	4	2026–2075	4–6
14 - South Kuroshio	1985–2021 2022–2025	4 8	2026–2075	8–10
15 - Ogasawara Islands	1985–2025	4	2026–2075	4–6
16 - Palawan/ North Borneo *	1985–2009 2010–2025	2 (3) 3 (4)	2026–2075	4–6
17 - Eastern Philippines *	1985–2009	3 (4)	2026–2075	8–10

Ecoregion	C1 – observed, past 50 years (1975–2025)		C2 – projected, future 50 years (2026–2075)	
	Timeframe	Widespread bleaching (DHW)	Timeframe	Widespread bleaching (DHW range)
	2010–2023 2024-2025	5 (6) 7 (8)		
18 - Sulawesi Sea/ Makassar Strait	1985–2025	6	2026–2075	6–8
19 - Halmahera	1985–2025	2	2026–2075	2–4
20 - Papua *	1985–2023 2024–2025	3 (4) 5 (6)	2026–2075	6–8
21 - Banda Sea *	1985–1997 1998–2019 2020–2025	1.5 (2.5) 3 (4) 5 (6)	2026–2075	6–8
22 - Lesser Sunda *	1985–2004 2005–2025	3 (4) 7 (8)	2026–2075	8–10
23 - Northeast Sulawesi	1985–2015 2016–2025	1 4	2026–2075	4–6
24 - Gulf of Papua	1985–2025	4	2026–2075	4–6
25 - Arafura Sea	1985–2025	4	2026–2075	4–6

Table 12 | Ecoregion-specific DHW thresholds representing thermal stress levels resulting in severe mortality for the pulse pathway. Thresholds can be time-varying to represent changing coral responses and increased warming. Mortality thresholds were set 2 DHW above the bleaching threshold of the same ecoregion and epoch, unless the literature documented higher thermal stress linked to widespread coral mortality, in which case the documented value was used. Asterisks (*) indicate the seven ecoregions initially assessed as LC under C1, where the thresholds applied were 1 DHW below the record-derived values (in brackets), while C2 ranges remain unchanged.

Ecoregion	C1 – observed, past 50 years (1975–2025)		C2 – projected, future 50 years (2026–2075)	
	Timeframe	Severe mortality (DHW)	Timeframe	Severe mortality (DHW range)
1 - Central Kuroshio Current	1985–2025	8	2026–2075	8–12
2 - East China Sea	1985–2025	8	2026–2075	8–12
3 - Northern Bay of Bengal - Myanmar	1985–2025	8	2026–2075	8–12
4 - Andaman Sea Coral Coast	1985–2009 2010–2025	4 6	2026–2075	6–10
5 - Western Sumatra *	1985–2015 2016–2025	5 (6) 7 (8)	2026–2075	8–12
6 - Gulf of Tonkin	1985–2015 2016–2019 2020–2025	6 8 10	2026–2075	10–14
7 - Southern China	1985–2025	8	2026–2075	8–12
8 - South China Sea Oceanic Islands	1985–2019 2020–2025	6 8	2026–2075	8–12
9 - Gulf of Thailand	1985–1997	5.5	2026–2075	6–10

Ecoregion	C1 – observed, past 50 years (1975–2025)		C2 – projected, future 50 years (2026–2075)	
	Timeframe	Severe mortality (DHW)	Timeframe	Severe mortality (DHW range)
	1998–2025	6		
10 - Southern Vietnam	1985–1997 1998–2009 2010–2025	4 5 6	2026–2075	6–10
11 - Sunda Shelf/ Java Sea *	1985–2025	5 (6)	2026–2075	6–10
12 - Malacca Strait	1985–1999 2000–2025	4 5	2026–2075	5–9
13 - Southern Java	1985–2025	6	2026–2075	6–10
14 - South Kuroshio	1985–2021 2022–2025	6 10	2026–2075	10–14
15 - Ogasawara Islands	1985–2025	8	2026–2075	8–12
16 - Palawan/ North Borneo *	1985–2009 2010–2025	4 (5) 7 (8)	2026–2075	8–12
17 - Eastern Philippines *	1985–2023 2024–2025	7 (8) 9 (10)	2026–2075	10–14
18 - Sulawesi Sea/ Makassar Strait	1985–2025	8	2026–2075	8–12
19 - Halmahera	1985–2025	6	2026–2075	6–10
20 - Papua *	1985–2023 2024–2025	5 (6) 7 (8)	2026–2075	8–12
21 - Banda Sea *	1985–1997 1998–2019 2020–2025	3.5 (4.5) 5 (6) 7 (8)	2026–2075	8–12
22 - Lesser Sunda *	1985–2004 2005–2025	5 (6) 9 (10)	2026–2075	10–14
23 - Northeast Sulawesi	1985–2015 2016–2025	3 6	2026–2075	6–10
24 - Gulf of Papua	1985–2025	8	2026–2075	8–12
25 - Arafura Sea	1985–2025	8	2026–2075	8–12

As a sensitivity test, sub-criterion C1 was also assessed with alternative thresholds set 1 DHW below the primary bleaching and mortality thresholds in all ecoregions. The only exception was Northeast Sulawesi (before 2016), where both thresholds were kept at their primary values, since lowering the 1 DHW bleaching threshold would have wrongly classified every year as an event.

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%). Under Criterion C2, the maximum risk status assigned was CR rather than CO, because CO denotes an ecosystem that has already collapsed while C2 is a risk based on future conditions. Therefore any ecoregions reaching 100% relative severity across 100% of reef extent were assigned CR rather than CO.

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).

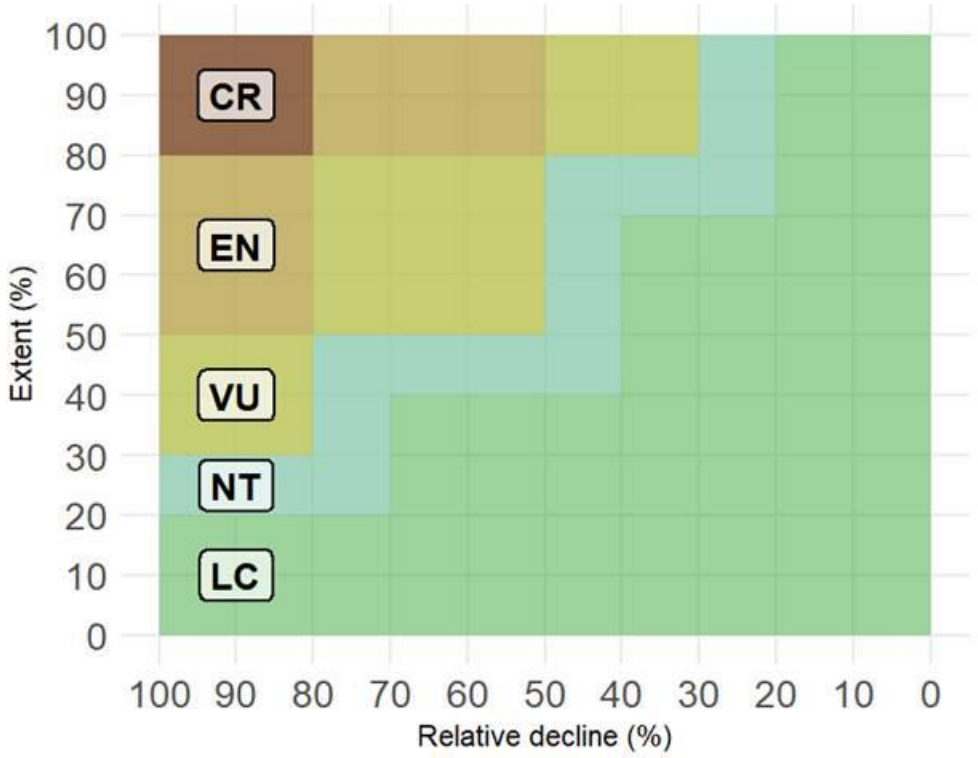


Figure 16 | Risk matrix - Relative extent of an ecosystem (y-axis) vs relative severity of decline (x-axis) used to assign risk classifications under Criterion C and D.

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 **East Asian region**, **four** key biotic components were assessed using data derived from standard underwater survey methods **(e.g. point intercept transects, line intercept transects, photo-quadrats and timed swims for benthic cover; underwater visual census along belt transects as well as timed swims for fish)**. 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 **macroalgae as reported by each contributing program, which combines fleshy and calcareous forms and excludes turf algae & encrusting crustose coralline algae (CCA)**, 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 (Scarinae) abundance, expressed as density of individuals per 100 m^2,** was used as a proxy, as **regional fish datasets were largely resolved at the family level and parrotfishes were among the most consistently recorded herbivores**.

For piscivory, **grouper (Epinephelidae) abundance, also expressed as density of individuals per 100 m^2,** was selected as suitable proxy for this trophic group because **they comprised the majority of piscivorous fish recorded in the available datasets, and are highly sensitive to fishing**. As noted in the Data section above, the lower taxonomic resolution of the GCRMN dataset required substituting Serranidae for Epinephelidae in several countries, which can inflate counts where Serranidae was recorded in the broad sense (including non-piscivorous genera such as *Anthias*).

Additional indicators such as coral recruitment, sea urchin abundance, coral community composition resolved to genus, measures of structural complexity or reef carbonate budget, could not be included due to insufficient spatial or temporal coverage.

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 for each site as the mean across all survey years available between **2020–2025**, with replicates and repeat surveys first averaged within each year. A *"site"* refers to a defined monitoring location where transects, quadrats, or other sampling units are situated, and at which data are aggregated.

In the final datasets used for the analyses of criterion D1, current values were available for 2,739 sites for hard coral cover, 2,228 sites for the algae-to-coral ratio, 1,986 sites for parrotfish density and 1,964 sites for grouper density.

However, since any given indicator can only be evaluated in ecoregions for which a baseline was available, only a subset of these sites were used for the assessment. Therefore, the risk calculation drew on 2,629 sites across 21 ecoregions for hard coral cover and on 1,349 sites across 12 ecoregions for the algae-to-coral ratio. In contrast, we used data from all available study sites for both fish indicators, since baselines were available for every ecoregion holding fish data. 3 records stemming from former reef sites in Singapore that have been buried by land reclamation within the 50-years assessment window were excluded from all Criterion D analyses. However, these lost reefs were retained under Criterion A since that criterion asks precisely how much reef has been lost.

Table 13 | Mean current value of each indicator per ecoregion (n stands for the number of monitoring sites).

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
1 - Central Kuroshio Current	Hard coral cover (%)	41	44.56	21.37	7.5	80
1 - Central Kuroshio Current	Algae:coral ratio	-	-	-	-	-
1 - Central Kuroshio Current	Parrotfish density (individuals per 100 m2)	23	0.17	0.15	0	0.67
1 - Central Kuroshio Current	Grouper density (individuals per 100 m2)	23	0.01	0.02	0	0.08

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
2 - East China Sea	Hard coral cover (%)	11	26.81	10.66	12.82	42.6
2 - East China Sea	Algae:coral ratio	11	0.288	0.211	0.012	0.563
2 - East China Sea	Parrotfish density (individuals per 100 m2)	11	0.45	0.66	0	2.33
2 - East China Sea	Grouper density (individuals per 100 m2)	11	0.1	0.12	0	0.31
3 - Northern Bay of Bengal - Myanmar	Hard coral cover (%)	28	28.17	23.09	1.49	85.64
3 - Northern Bay of Bengal - Myanmar	Algae:coral ratio	28	0.153	0.313	0	0.914
3 - Northern Bay of Bengal - Myanmar	Parrotfish density (individuals per 100 m2)	25	7.91	10.73	0	45.33
3 - Northern Bay of Bengal - Myanmar	Grouper density (individuals per 100 m2)	4	0.54	0.29	0.13	0.82
4 - Andaman Sea Coral Coast	Hard coral cover (%)	75	51.65	22.24	8.6	96
4 - Andaman Sea Coral Coast	Algae:coral ratio	57	0.011	0.04	0	0.234
4 - Andaman Sea Coral Coast	Parrotfish density (individuals per 100 m2)	71	1.95	2.24	0	10.42
4 - Andaman Sea Coral Coast	Grouper density (individuals per 100 m2)	71	2.07	4.29	0	29.33
5 - Western Sumatra	Hard coral cover (%)	49	35.08	16.42	0.6	62
5 - Western Sumatra	Algae:coral ratio	49	0.085	0.177	0	0.842
5 - Western Sumatra	Parrotfish density (individuals per 100 m2)	56	4.61	7.08	0	38.29
5 - Western Sumatra	Grouper density	57	0.83	1.26	0	6.29

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
	(individuals per 100 m2)					
6 - Gulf of Tonkin	Hard coral cover (%)	25	27.59	16.84	5.54	71.74
6 - Gulf of Tonkin	Algae:coral ratio	25	0.166	0.19	0	0.75
6 - Gulf of Tonkin	Parrotfish density (individuals per 100 m2)	10	0.21	0.19	0	0.5
6 - Gulf of Tonkin	Grouper density (individuals per 100 m2)	10	1.71	0.85	0.75	3.25
7 - Southern China	Hard coral cover (%)	39	41.07	16.35	9.69	70.21
7 - Southern China	Algae:coral ratio	7	0.049	0.036	0	0.092
7 - Southern China	Parrotfish density (individuals per 100 m2)	11	0.54	0.71	0	2.4
7 - Southern China	Grouper density (individuals per 100 m2)	11	0.15	0.17	0	0.5
8 - South China Sea Oceanic Islands	Hard coral cover (%)	27	15.7	11.54	1.47	32.94
8 - South China Sea Oceanic Islands	Algae:coral ratio	27	0.145	0.218	0	0.717
8 - South China Sea Oceanic Islands	Parrotfish density (individuals per 100 m2)	-	-	-	-	-
8 - South China Sea Oceanic Islands	Grouper density (individuals per 100 m2)	-	-	-	-	-
9 - Gulf of Thailand	Hard coral cover (%)	143	45.5	18.08	8.94	90.35
9 - Gulf of Thailand	Algae:coral ratio	115	0.031	0.086	0	0.529
9 - Gulf of Thailand	Parrotfish density (individuals per 100 m2)	150	2.63	3.85	0	25.62

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
9 - Gulf of Thailand	Grouper density (individuals per 100 m2)	150	1.38	1.27	0	7.11
10 - Southern Vietnam	Hard coral cover (%)	53	14.42	13.96	0.27	50.62
10 - Southern Vietnam	Algae:coral ratio	53	0.47	0.34	0.004	0.979
10 - Southern Vietnam	Parrotfish density (individuals per 100 m2)	41	8	7.41	0	26.38
10 - Southern Vietnam	Grouper density (individuals per 100 m2)	41	0.7	0.83	0	3.38
11 - Sunda Shelf/ Java Sea	Hard coral cover (%)	203	51.92	19.81	2.5	88.63
11 - Sunda Shelf/ Java Sea	Algae:coral ratio	203	0.086	0.117	0	0.754
11 - Sunda Shelf/ Java Sea	Parrotfish density (individuals per 100 m2)	192	6.85	14.26	0	89.14
11 - Sunda Shelf/ Java Sea	Grouper density (individuals per 100 m2)	194	0.85	0.79	0	4.67
12 - Malacca Strait	Hard coral cover (%)	40	32.65	16.34	6.41	78.62
12 - Malacca Strait	Algae:coral ratio	40	0.17	0.185	0	0.642
12 - Malacca Strait	Parrotfish density (individuals per 100 m2)	27	1.8	2.57	0	9.12
12 - Malacca Strait	Grouper density (individuals per 100 m2)	27	1.56	1.26	0	4.92
13 - Southern Java	Hard coral cover (%)	20	33.5	22.24	4	99.64
13 - Southern Java	Algae:coral ratio	20	0.19	0.201	0	0.62
13 - Southern Java	Parrotfish density	14	26.12	8.31	11.43	40.57

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
	(individuals per 100 m2)					
13 - Southern Java	Grouper density (individuals per 100 m2)	20	3.79	3.31	0	8.86
14 - South Kuroshio	Hard coral cover (%)	417	29.69	20.33	0.5	80
14 - South Kuroshio	Algae:coral ratio	52	0.405	0.328	0	0.945
14 - South Kuroshio	Parrotfish density (individuals per 100 m2)	402	0.34	0.63	0	5.25
14 - South Kuroshio	Grouper density (individuals per 100 m2)	401	0.03	0.05	0	0.45
15 - Ogasawara Islands	Hard coral cover (%)	12	49.69	18.21	23.75	76.25
15 - Ogasawara Islands	Algae:coral ratio	-	-	-	-	-
15 - Ogasawara Islands	Parrotfish density (individuals per 100 m2)	12	0.19	0.1	0	0.33
15 - Ogasawara Islands	Grouper density (individuals per 100 m2)	12	0.08	0.04	0	0.12
16 - Palawan/ North Borneo	Hard coral cover (%)	291	30.36	15.63	1.07	74.62
16 - Palawan/ North Borneo	Algae:coral ratio	291	0.231	0.284	0	0.977
16 - Palawan/ North Borneo	Parrotfish density (individuals per 100 m2)	203	2.62	2.89	0	25.75
16 - Palawan/ North Borneo	Grouper density (individuals per 100 m2)	214	0.43	0.77	0	7
17 - Eastern Philippines	Hard coral cover (%)	260	23.2	17.54	0	100
17 - Eastern Philippines	Algae:coral ratio	256	0.23	0.275	0	1

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
17 - Eastern Philippines	Parrotfish density (individuals per 100 m2)	215	4.02	3.66	0	17.73
17 - Eastern Philippines	Grouper density (individuals per 100 m2)	211	1.22	2.15	0	19.8
18 - Sulawesi Sea/Makassar Strait	Hard coral cover (%)	171	47.1	17.01	6.4	99
18 - Sulawesi Sea/Makassar Strait	Algae:coral ratio	171	0.064	0.106	0	0.701
18 - Sulawesi Sea/Makassar Strait	Parrotfish density (individuals per 100 m2)	93	4.86	4.24	0	24.86
18 - Sulawesi Sea/Makassar Strait	Grouper density (individuals per 100 m2)	92	0.49	0.56	0	2.67
19 - Halmahera	Hard coral cover (%)	83	37.27	13.57	13.17	74.26
19 - Halmahera	Algae:coral ratio	83	0.086	0.146	0	0.788
19 - Halmahera	Parrotfish density (individuals per 100 m2)	-	-	-	-	-
19 - Halmahera	Grouper density (individuals per 100 m2)	-	-	-	-	-
20 - Papua	Hard coral cover (%)	41	32.84	17.02	4.33	83
20 - Papua	Algae:coral ratio	41	0.138	0.203	0	0.678
20 - Papua	Parrotfish density (individuals per 100 m2)	60	8.52	12.68	0.6	73.71
20 - Papua	Grouper density (individuals per 100 m2)	60	0.92	2.14	0	8.86
21 - Banda Sea	Hard coral cover (%)	442	36.55	20.06	0	90.91

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
21 - Banda Sea	Algae:coral ratio	431	0.123	0.171	0	0.954
21 - Banda Sea	Parrotfish density (individuals per 100 m2)	321	1.94	2.59	0	17.33
21 - Banda Sea	Grouper density (individuals per 100 m2)	317	0.29	0.44	0	3.71
22 - Lesser Sunda	Hard coral cover (%)	239	35.3	17.26	0	100
22 - Lesser Sunda	Algae:coral ratio	239	0.161	0.196	0	1
22 - Lesser Sunda	Parrotfish density (individuals per 100 m2)	35	5.31	7.23	0	25.71
22 - Lesser Sunda	Grouper density (individuals per 100 m2)	24	0.19	0.32	0	1.14
23 - Northeast Sulawesi	Hard coral cover (%)	29	52.34	10.99	19.15	72.33
23 - Northeast Sulawesi	Algae:coral ratio	29	0.069	0.052	0	0.221
23 - Northeast Sulawesi	Parrotfish density (individuals per 100 m2)	7	2.6	2.68	0	6.4
23 - Northeast Sulawesi	Grouper density (individuals per 100 m2)	7	0.4	0.51	0	1.2
24 - Gulf of Papua	Hard coral cover (%)	-	-	-	-	-
24 - Gulf of Papua	Algae:coral ratio	-	-	-	-	-
24 - Gulf of Papua	Parrotfish density (individuals per 100 m2)	7	5	3.98	1	12.07
24 - Gulf of Papua	Grouper density (individuals per 100 m2)	7	0	0	0	0.01

Ecoregion	Indicator	n	Mean	Std. dev.	Min. value	Max. value
25 - Arafura Sea	Hard coral cover (%)	-	-	-	-	-
25 - Arafura Sea	Algae:coral ratio	-	-	-	-	-
25 - Arafura Sea	Parrotfish density (individuals per 100 m2)	-	-	-	-	-
25 - Arafura Sea	Grouper density (individuals per 100 m2)	-	-	-	-	-

Initial values

A **reference state** representing conditions of each indicator approximately 50 years ago (circa 1975) was established to quantify long-term change. Monitoring data from this period were generally **limited**, as consistent and standardised reef monitoring **began in the mid-1980s at the earliest, and only in the late 1990s or 2000s in most ecoregions**.

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

To determine the most suitable approach for deriving initial values, the first step was to consider the likely condition of reefs in each ecoregion in the mid-1970s for the selected indicators, specifically, whether reefs were in better condition, relatively pristine, or already degraded.

Method 1 – Literature-derived benthic baselines

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. Several reefs prior to 1998 were considered broadly representative of earlier (1970s) conditions, with only localised degradation in places.

A literature review was conducted to compile benthic data from early reef surveys, primarily from the 1980s and 1990s. However, the early monitoring records (pre-1998) extracted from the literature and/or available in the contributed monitoring datasets did not yield sufficient early ecoregion-specific **hard coral and algae cover** values with adequate spatial coverage. Hence, method 1 was not applied as a core method to derive benthic baselines in the East Asian assessment. The few retrieved early monitoring records were instead retained as an independent cross-check on the values derived through the usage of Method 2 (see below).

Method 2 – Maximum value approach

An alternative approach used long-term monitoring datasets to estimate baseline conditions. Sites with extended time series **(a minimum of two survey years spanning at least ten years)** were assumed to have experienced relatively good conditions at some point during the monitoring period. These records can provide an estimate of the 'best' conditions possible across reefs in an ecoregion, therefore acting as a proxy for "healthy" conditions around 1975.

For each site, the maximum recorded value of each indicator (e.g. highest coral cover) across its monitoring history was extracted. Sites whose maximum was recorded in 2024 or 2025 were excluded, so that the 2024 global bleaching event could not influence the benthic baselines. Furthermore, we also excluded sites whose maximum hard coral cover across the whole monitoring time-series never exceeded 5%, as these sites were assumed to be already degraded. The maximum values across all these long-term monitoring sites within each ecoregion were then used to estimate a baseline distribution (mean and standard deviation). Where available, these estimates were compared with published historical survey data (1960s–1990s) for validation. This procedure yielded hard coral baselines computed from 745 sites across 14 ecoregions.

Baseline values for macroalgae cover, which was later used to estimate the algae-to-coral ratio, were selected on the same reference condition. For any given site, macroalgae baselines were chosen in the same year as the observed maximum hard coral cover value in the time-series.

The approach outlined above left 8 ecoregions with current hard coral cover data but no initial values (Banda Sea, Gulf of Papua, Northeast Sulawesi, Northern Bay of Bengal - Myanmar, Papua, Southern Java, Sulawesi Sea/Makassar Strait and Western Sumatra). These ecoregions held benthic time-series of close to 10 years, sufficient to characterise their current condition, but not extending far enough back to derive a baseline under the selection rule outlined above. To fill this gap, hard coral baselines were borrowed from the biogeographically most comparable ecoregions (located nearby, holding similar hard coral cover values and with sufficiently long time-series of benthic data), with the borrowed baseline mean computed as the mean of the donor ecoregions' baselines. The standard deviation was set to a region-wide value across the whole of East Asia (computed as the mean of the ecoregion-level standard deviations), following the convention used in the Western Indian Ocean assessment (Obura et al., 2022). Where early (pre-1998) monitoring records existed for an ecoregion borrowing hard coral cover baselines, the borrowed value was compared against them and retained only where the two agreed to within one regional standard deviation. Through this borrowing process, 7 of the 8 ecoregions borrowed hard coral cover baselines, bringing the evaluation from 14 to 21 of the 25 ecoregions. The Gulf of Papua was not retained because it holds no benthic survey data from 2020 onwards, so there is no record of its current condition against which a borrowed baseline could be evaluated. Four Ecoregions (South China Sea Oceanic Islands, Halmahera, Gulf of Papua, Arafura Sea) for which neither a direct nor a defensible borrowed baseline could be selected were reported as Data Deficient and thus not evaluated under criterion D1. This borrowing scheme was

applied only to hard coral cover. Baselines for the algae-to-coral ratio require a macroalgae cover value being recorded in the year of maximum hard coral cover at each site, and this could be obtained only for 12 out of the 25 ecoregions assessed. The algae-to-coral ratio could therefore not be evaluated in the 7 ecoregions that borrowed hard coral cover baselines, leaving 780 benthic monitoring sites excluded from this indicator.

Table 14 | Mean, standard deviation, minimum and maximum initial values of **hard coral cover** (%) in each ecoregion (n = number of sites)**, including the source of each baseline** (observed or borrowed, with donor ecoregions named).

Ecoregion	Observed/borrowed (donor)	Mean	Std. dev.	Min. value	Max. value	n
1 - Central Kuroshio Current	Observed	49.62	18.49	10	75.8	34
2 - East China Sea	Observed	41.4	9.41	27.29	55	6
3 - Northern Bay of Bengal - Myanmar	Borrowed (Andaman Sea Coral Coast)	46.82	16.89	10.53	89.5	21
4 - Andaman Sea Coral Coast	Observed	46.82	23.98	10.53	89.5	21
5 - Western Sumatra	Borrowed (Andaman Sea Coral Coast)	46.82	16.89	10.53	89.5	21
6 - Gulf of Tonkin	Observed	34.28	14.96	10	57.33	15
7 - Southern China	Observed	57.56	13.72	25.56	75.45	12
8 - South China Sea Oceanic Islands	-	-	-	-	-	-
9 - Gulf of Thailand	Observed	54.51	18.32	13.3	90.35	53
10 - Southern Vietnam	Observed	40.66	21.07	7.5	89.38	34
11 - Sunda Shelf/Java Sea	Observed	68.11	15.64	15	97.5	69
12 - Malacca Strait	Observed	46.35	17.72	20.32	88.75	24
13 - Southern Java	Borrowed (Lesser Sunda)	54.54	16.89	19.83	77.17	18
14 - South Kuroshio	Observed	56.46	23.11	5.43	100	366
15 - Ogasawara Islands	Observed	56.36	20.6	30	92.5	11
16 - Palawan/North Borneo	Observed	52.22	15.5	15.94	91.88	78
17 - Eastern Philippines	Observed	22.83	8.45	15.53	34.98	4

Ecoregion	Observed/borrowed (donor)	Mean	Std. dev.	Min. value	Max. value	n
18 - Sulawesi Sea/Makassar Strait	Borrowed (Palawan/North Borneo)	52.22	16.89	15.94	91.88	78
19 - Halmahera	-	-	-	-	-	-
20 - Papua	Borrowed (Lesser Sunda)	54.54	16.89	19.83	77.17	18
21 - Banda Sea	Borrowed (Lesser Sunda)	54.54	16.89	19.83	77.17	18
22 - Lesser Sunda	Observed	54.54	15.53	19.83	77.17	18
23 - Northeast Sulawesi	Borrowed (Palawan/North Borneo)	52.22	16.89	15.94	91.88	78
24 - Gulf of Papua	-	-	-	-	-	-
25 - Arafura Sea	-	-	-	-	-	-

Fish baseline estimation

Baseline values for fish indicators were estimated using a space-for-time substitution approach. Fishing pressure was assumed to have been **lower** in the 1970s, and therefore fish populations were likely higher than present. However, in much of Southeast Asia, the period between the 1970s and 1990s was also marked by widespread destructive fishing practices (e.g. blast fishing, cyanide fishing, muro-ami, trawling), which partly offsets the increased fishing pressure from more modern fleets and growing demand at present. A close approximation for these higher fish populations comes from well-managed, no-take marine protected areas (MPAs) with at least 10 years of protection and from reefs with a well-documented reputation for high fish biomass (e.g. remote reefs). Such reef sites were also assumed to be representative of other reefs in the ecoregion. Yet in this East Asian RLE assessment, neither no-take status nor protection duration was applied as a strict cut-off to allow for the retention of sufficient reference sites across the region. Furthermore, survey years were not restricted to the period after designation, so three reference areas (Amamigunto, Keramashoto and Tun Mustapha Park) also include data from earlier surveys. This methodological choice likely lowered the baselines of the South Kuroshio and Palawan/North Borneo ecoregions (see Discussion).

In total, 16 reference areas (332 reference sites) located in 10 of the 22 ecoregions with fish data were compiled across the region (Table 15). These reference areas ranged from no-take zones, to multiple-use marine parks, and five of them were also selected for their reputation as high-biomass reefs. All reference sites chosen are located within gazetted protected areas. To obtain fish baselines, we first calculated mean abundance (density) across all available survey years (1997–2025) for each reference site before deriving the ecoregion baseline

distribution (mean, standard deviation, minimum and maximum; Table 16) from these site means. The reasoning behind this methodological step was to ensure that each site was equally represented in the ecoregion average, so that heavily surveyed reef sites do not dominate the fish baseline values. Where such reference sites were unavailable, estimates from ecoregions with the most similar reefs were used. Published estimates of fish abundance and biomass on near-pristine or long-protected reefs were used to qualitatively check the plausibility of the calculated baselines. Although few and often not directly comparable, they were broadly consistent with the baselines derived in this assessment.

Table 15 | Reference areas used to calculate fish density baselines for Criterion D. Protection status and year of designation were retrieved from the World Database on Protected Areas (UNEP-WCMC and IUCN 2026) with the *wdpar* R package (Version 1.3.9, Hanson 2022). Baseline survey years indicate the range of survey years, and monitoring sites (n) the number of survey sites per reference area that were used to calculate baselines.

Reference area	Country	Ecoregion	Basis for selection	Protected since	Baseline survey years	Monitoring sites (n)
Samut Kaoh Rung	Cambodia	Gulf of Thailand	marine park	2016	2019–2025	20
Selat Dampier (Raja Ampat)	Indonesia	Papua	high-biomass reef; no-take zone	2007	2021	12
Amamigunto	Japan	South Kuroshio	marine park	2021	2001–2025	1
Keramashoto	Japan	South Kuroshio	marine park	2014	2000–2025	13
Ogasawara	Japan	Ogasawara Islands	marine park; high-biomass reef	2011	2018–2025	12
Pulau Perhentian Kecil Marine Park; Pulau Perhentian Besar Marine Park; Pulau Redang Marine Park; Pulau Tenggol Marine Park; Pulau Tioman Marine Park	Malaysia	Sunda Shelf/Java Sea	marine park	1994	1997–2025	81
Sipadan Island Park	Malaysia	Palawan/North Borneo	no-take zone; high-biomass reef	2004	2004–2025	12
Tun Mustapha Park	Malaysia	Palawan/North Borneo	marine park	2016	2009–2025	29
Tun Sakaran Marine Park	Malaysia	Palawan/North Borneo	marine park; high-biomass reef	2004	2020–2025	6
Lampi Marine National Park	Myanmar	Andaman Sea Coral Coast; Northern Bay of Bengal	marine park	1996	2024–2025	34

Reference area	Country	Ecoregion	Basis for selection	Protected since	Baseline survey years	Monitoring sites (n)
Kenting	Taiwan	South Kuroshio	marine park	1984	2019–2025	8
Muko Ang Thong; Khao Laem Ya - Mu Ko Samet; Mu ko Chang	Thailand	Gulf of Thailand	marine park	1980	2023–2025	31
Muko Surin; Mu Ko Similan	Thailand	Andaman Sea Coral Coast	marine park; high-biomass reef	1983	2023–2025	31
Con Dao	Vietnam	Southern Vietnam	no-take zone	1993	2018–2025	16
Cu Lao Cham (marine)	Vietnam	Gulf of Tonkin	marine park	2005	2023–2025	10
Phu Quoc	Vietnam	Gulf of Thailand	marine park	2007	2019–2025	16

For ecoregions that did not contain any reference area, baselines were borrowed following a logic similar to that applied for hard coral cover. Specifically, we implemented a donor scheme that assigns baselines to a given ecoregion from the biogeographically most similar ecoregion holding reference sites. For example, the Banda Sea and Lesser Sunda borrowed baselines from Papua, being nearby, located within the Coral Triangle and considered comparable. The distribution (mean, standard deviation, minimum, maximum) was borrowed for both parrotfish and grouper from the pre-defined donor ecoregion, and donor assignments were reviewed with regional experts. In contrast to hard coral cover, the standard deviation was not replaced by a regional value. Overall, 12 ecoregions borrowed fish baselines from six donor ecoregions. Borrowing was applied iteratively over five passes, so that an ecoregion whose donor had itself borrowed could still inherit a baseline through a chain of donors.

Table 16 | Mean initial values with variance measures calculated from reference MPA sites for **parrotfish and grouper indicators** for each ecoregion. Mean, standard deviation, minimum and maximum value are expressed as densities (no. individuals per 100m2), while n represents the number of reference sites considered in each ecoregion (for borrowed baselines it corresponds to those of the donor ecoregion). This table also provides the source of each baseline (observed or borrowed), with donor ecoregions indicated in brackets. Dashes indicate ecoregions without fish data.

Ecoregion	Indicator	Observed/ borrowed (donor)	Mean	Std. dev	Min value	Max value	n
1 - Central Kuroshio Current	Parrotfish	Borrowed (South Kuroshio)	1.044	1.323	0	5.25	22
2 - East China Sea	Parrotfish	Borrowed (South Kuroshio)	1.044	1.323	0	5.25	22
3 - Northern Bay of Bengal - Myanmar	Parrotfish	Observed	0.833	1.059	0	2.367	4

Ecoregion	Indicator	Observed/ borrowed (donor)	Mean	Std. dev	Min value	Max value	n
4 - Andaman Sea Coral Coast	Parrotfish	Observed	1.934	2.11	0	10.422	61
5 - Western Sumatra	Parrotfish	Borrowed (Andaman Sea Coral Coast)	1.934	2.11	0	10.422	61
6 - Gulf of Tonkin	Parrotfish	Observed	0.206	0.189	0	0.5	10
7 - Southern China	Parrotfish	Borrowed (Southern Vietnam)	5.758	5.648	1.75	24.75	16
8 - South China Sea Oceanic Islands	Parrotfish	-	-	-	-	-	-
9 - Gulf of Thailand	Parrotfish	Observed	3.25	4.435	0	25.625	67
10 - Southern Vietnam	Parrotfish	Observed	5.758	5.648	1.75	24.75	16
11 - Sunda Shelf/ Java Sea	Parrotfish	Observed	3.209	2.485	0	13.179	79
12 - Malacca Strait	Parrotfish	Borrowed (Sunda Shelf/Java Sea)	3.209	2.485	0	13.179	79
13 - Southern Java	Parrotfish	Borrowed (Papua)	28.143	17.178	12.857	73.714	12
14 - South Kuroshio	Parrotfish	Observed	1.044	1.323	0	5.25	22
15 - Ogasawara Islands	Parrotfish	Observed	0.192	0.097	0.003	0.333	12
16 - Palawan/ North Borneo	Parrotfish	Observed	4.37	4.179	0.75	25.75	47
17 - Eastern Philippines	Parrotfish	Borrowed (Palawan/North Borneo)	4.37	4.179	0.75	25.75	47
18 - Sulawesi Sea/ Makassar Strait	Parrotfish	Borrowed (Palawan/North Borneo)	4.37	4.179	0.75	25.75	47
19 - Halmahera	Parrotfish	-	-	-	-	-	-
20 - Papua	Parrotfish	Observed	28.143	17.178	12.857	73.714	12
21 - Banda Sea	Parrotfish	Borrowed (Papua)	28.143	17.178	12.857	73.714	12
22 - Lesser Sunda	Parrotfish	Borrowed (Papua)	28.143	17.178	12.857	73.714	12
23 - Northeast Sulawesi	Parrotfish	Borrowed (Papua)	28.143	17.178	12.857	73.714	12
24 - Gulf of Papua	Parrotfish	Borrowed (Papua)	28.143	17.178	12.857	73.714	12
25 - Arafura Sea	Parrotfish	-	-	-	-	-	-

Ecoregion	Indicator	Observed/ borrowed (donor)	Mean	Std. dev	Min value	Max value	n
1 - Central Kuroshio Current	Grouper	Borrowed (South Kuroshio)	0.088	0.117	0	0.45	22
2 - East China Sea	Grouper	Borrowed (South Kuroshio)	0.088	0.117	0	0.45	22
3 - Northern Bay of Bengal - Myanmar	Grouper	Observed	0.544	0.294	0.133	0.822	4
4 - Andaman Sea Coral Coast	Grouper	Observed	2.297	4.577	0	29.333	61
5 - Western Sumatra	Grouper	Borrowed (Andaman Sea Coral Coast)	2.297	4.577	0	29.333	61
6 - Gulf of Tonkin	Grouper	Observed	1.706	0.85	0.75	3.25	10
7 - Southern China	Grouper	Borrowed (Southern Vietnam)	1.38	0.974	0	3.375	16
8 - South China Sea Oceanic Islands	Grouper	-	-	-	-	-	-
9 - Gulf of Thailand	Grouper	Observed	1.602	1.688	0	7.111	67
10 - Southern Vietnam	Grouper	Observed	1.38	0.974	0	3.375	16
11 - Sunda Shelf/ Java Sea	Grouper	Observed	0.628	0.536	0	2.469	81
12 - Malacca Strait	Grouper	Borrowed (Sunda Shelf/Java Sea)	0.628	0.536	0	2.469	81
13 - Southern Java	Grouper	Borrowed (Papua)	4.595	2.48	1.429	8.857	12
14 - South Kuroshio	Grouper	Observed	0.088	0.117	0	0.45	22
15 - Ogasawara Islands	Grouper	Observed	0.079	0.035	0	0.125	12
16 - Palawan/ North Borneo	Grouper	Observed	0.666	0.659	0	2.75	47
17 - Eastern Philippines	Grouper	Borrowed (Palawan/North Borneo)	0.666	0.659	0	2.75	47
18 - Sulawesi Sea/ Makassar Strait	Grouper	Borrowed (Palawan/North Borneo)	0.666	0.659	0	2.75	47
19 - Halmahera	Grouper	-	-	-	-	-	-
20 - Papua	Grouper	Observed	4.595	2.48	1.429	8.857	12
21 - Banda Sea	Grouper	Borrowed (Papua)	4.595	2.48	1.429	8.857	12
22 - Lesser Sunda	Grouper	Borrowed (Papua)	4.595	2.48	1.429	8.857	12

Ecoregion	Indicator	Observed/ borrowed (donor)	Mean	Std. dev	Min value	Max value	n
23 - Northeast Sulawesi	Grouper	Borrowed (Papua)	4.595	2.48	1.429	8.857	12
24 - Gulf of Papua	Grouper	Borrowed (Papua)	4.595	2.48	1.429	8.857	12
25 - Arafura Sea	Grouper	-	-	-	-	-	-

Collapse thresholds

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

For benthic indicators, thresholds reflect a transformation in state, for example away from a coral-dominated ecosystem to one which is algae-dominated. For fish indicators, thresholds represented the loss of ecological function (e.g. insufficient herbivory or piscivory to influence ecosystem dynamics). Thresholds were based on **published studies, empirical observations, and expert judgment**, and were applied **consistently** across all ecoregions.

For hard coral cover, a threshold of **5%** was applied, representing the minimum level required to sustain positive carbonate accretion on a reef. This is a deliberate departure from the 10% used in the Western Indian Ocean assessment (Obura et al., 2022), and it was adopted for consistency with the other regions assessing coral reef risk status under the RLE framework.

For the algae-to-coral ratio, a collapse threshold of **0.833** (i.e. algae cover five times greater than coral cover, corresponding to a ratio of 5:1) was used, indicating a persistent shift to algal dominance where recovery becomes unlikely.

For fish indicators, thresholds were defined relative to baseline conditions, with collapse occurring at **10%** of baseline levels for parrotfish and **20%** for groupers.

Calculating relative severity of decline

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

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

Relative severity was bounded between 0 and 100%, and sites at or beyond the collapse threshold were set to 100%. Uncertainty in initial conditions was incorporated by applying a bootstrapping approach. For each ecoregion and indicator, initial values were represented as a truncated normal distribution defined by the estimated mean, standard deviation, and observed range (min and max) of the indicator across all records in that ecoregion. Initial

values were randomly sampled independently at every iteration from this ecoregional distribution and assigned to each site.

The highest risk category was determined from the decline-extent matrix (Fig. 16), with the ecosystem extent calculated as the proportion of sites exceeding decline thresholds (≥20%, ≥30%, ≥40%, ≥50%, ≥70%, ≥80%, and 100% decline). This process was repeated **1000** 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 (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).

In the East Asian RLE assessment, biotic indicator coverage differed between components. Hard coral cover trends were evaluated for 14 ecoregions from directly derived baselines, and a further 7 from borrowed baselines (as outlined earlier). Algae-to-coral ratio was assessed for 12 ecoregions only (because of lack of macroalgae cover baselines), while the two fish indicators were evaluated for 22 ecoregions each. Since hard coral cover is considered the foundational indicator for criterion D1, we assigned a final risk status under

Criterion D to an ecoregion only if this component was assessed, resulting in 21 risk statuses assigned for this criterion. Consequently, 4 ecoregions (South China Sea Oceanic Islands, Halmahera, Gulf of Papua, Arafura Sea) with insufficient monitoring data coverage were classified as Data Deficient.

If an indicator could not be assessed, for instance the algal-coral ratio for ecoregions without macroalgae baselines, the stepwise evaluation scheme proceeded to the next available indicator, with the reduced evidence base noted accordingly.

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.

Discussion

In this study, we found that coral reefs across East Asia face a very high risk of collapse. This dire future scenario was mainly driven by projected ocean warming assessed under Criterion C, which led to all 25 ecoregions being assessed as Critically Endangered. This outcome was sustained even with the adoption of an intermediate emissions pathway (SSP2–4.5), representing a more optimistic scenario as compared to the world's current emission trajectory. The remaining criteria assessed returned a more varied picture. Based on historical declines and present conditions alone (Criteria A, B, C1 and D), 22 of the 25 ecoregions are assessed as threatened, among which only five are Critically Endangered.

Heat stress over the past 50 years, which was assessed under sub-criterion C1, followed a clear spatial pattern. In fact, all ecoregions assessed as Critically Endangered or Endangered lie at the margins of the region, with six located in the north (Central Kuroshio Current, East China Sea, Southern China, South Kuroshio, Ogasawara Islands and Gulf of Tonkin), one in the west (Northern Bay of Bengal) and three in the south (Southern Java, Arafura Sea and Gulf of Papua). In contrast, no ecoregion located in the Coral Triangle exceeded Vulnerable, and five of the eight are Near Threatened or Least Concern. Globally, mass coral bleaching has been reported to have lower probability of occurrence near the equator than at 15–20° latitude, despite similar heat stress (Ferris et al., 2025). It has also been less frequent where sea surface temperatures are more variable (Sully et al., 2019). Both patterns may explain the lower prevalence of bleaching in parts of the Coral Triangle which lie close to the equator and include areas of high temperature variability such as Papua (Huffard et al., 2012). In addition,

oceanographic processes such as localized upwelling and the Indonesian Throughflow might further buffer these regions from sustained heat stress (Gordon, 2005; Wirasatriya et al., 2023).

It is important to note that a Least Concern risk status under C1 does not necessarily imply that reefs in these ecoregions completely escaped the impacts of warming. In fact, this result may indicate that severe bleaching and mortality events were too infrequent or too limited in extent to raise the risk of collapse at the ecoregion scale. For instance, even though the 2010 heatwave reportedly killed 94 % of *Acropora* and 87 % of *Pocillopora* colonies at Pulau Weh in northern Sumatra (Guest et al., 2012), the Western Sumatra ecoregion was assessed as Least Concern. Furthermore, since this risk category requires that an ecosystem unambiguously meets none of the quantitative criteria (IUCN, 2024), we lowered the DHW thresholds by 1 DHW for the seven ecoregions initially assessed as Least Concern (see Methods). This accounts for bleaching and mortality that may have gone unreported in some years, as the record-derived thresholds would then overestimate the heat stress needed to cause such events. With these lower thresholds, the Banda Sea and Palawan/North Borneo ecoregions went from Least Concern to Vulnerable, while Eastern Philippines and Sunda Shelf/Java Sea changed to Near Threatened. However, even with these adapted thresholds, the ecoregions Papua, Lesser Sunda and Western Sumatra remained Least Concern, suggesting that their risk status is not an artifact of the thresholds adopted. In sum, the unchanged status of these three ecoregions most likely reflects severe events that were limited in extent at the ecoregion scale, but this does not rule out local impacts, such as at Pulau Weh.

According to current projections, the frequency and intensity of potentially damaging marine heatwaves is forecasted to increase drastically (Mellin et al., 2024). While the threat to East Asian coral reefs is already evident from the observed heat stress (assessed under Criterion C1), we expect it to intensify in the near future, requiring strong and rapid climate action. However, it is important to note that a Critically Endangered status under C2 does not imply that every reef will collapse, but rather that there is a high likelihood of collapse at the ecosystem level. Furthermore, the DHW projections apply uniform warming across large areas of reef, likely failing to capture fine-scale differences in exposure. At the same time, because coral communities differ in their responses to heat stress, we adopted ecoregion-specific DHW thresholds that could be modified based on past records of bleaching and mortality. This methodological step led to increasing thresholds in several ecoregions, which may reflect an increase in tolerance to thermal stress (adaptation to warming, Lachs et al., 2023). In fact, such an increase in thermal tolerance of coral reefs has been documented globally over the past decades, with the onset of bleaching shifting to higher temperatures (Sully et al., 2019). This trend is also visible across East Asia, where reefs that had already bleached in the past have responded less severely to later heatwaves. For instance, only 5 % of *Acropora* colonies died in Singapore after the 2010 heatwave compared to 94 % at Pulau Weh, despite similar estimated thermal stress. Unlike Pulau Weh, Singapore's reefs had already bleached in 1998, suggesting that local corals had adapted or acclimatised to past levels of heat stress (Guest et al., 2012). In addition, several reefs in Taiwan and Okinawa

have been observed to effectively recover between recurrent bleaching events (Keshavmurthy et al., 2019; Afzal et al., 2025), hinting at an increase in resilience. Despite the high risk of collapse, there is thus still hope that some coral communities in East Asia may resist or recover from thermal stress better than others. These resilient reefs should be identified and prioritised for protection from additional local stressors.

In contrast to heat stress, hard coral cover remained relatively stable across most of the region, consistent with the decadal stability reported for East Asian reefs (Chan et al., 2023; Kimura et al., 2026b). The loss of reef area assessed under Criterion A, showed that only Southern Vietnam and the South China Sea Oceanic Islands reached a threatened category, and both ecoregions have a long documented history of habitat loss (Hughes et al., 2013; Tkachenko et al., 2023). However, we acknowledge that the remarkable stability in this benthic indicator in East Asia can mask shifts between coral communities towards an increased prevalence of stress-tolerant taxa (Chan et al., 2023). The low risk under Criterion A and for hard coral cover under Criterion D may therefore mask ongoing changes in reef composition. The results of Criterion A are also sensitive to the choice of the hard coral cover threshold used to define the collapsed state of reef sites. The 10% hard coral cover threshold adopted here is higher than the 5% used in most other regions of this RLE assessment, and applying 5% would lower the risk status of four ecoregions (Fig. S3).

Biotic disruption across East Asia, assessed under Criterion D, was mainly driven by fish indicators. In fact, the hard coral cover indicator reached a threatened category in only four of the 21 ecoregions assessed, compared to 14 of 22 ecoregions for parrotfish and 15 of 22 for groupers. As a result, fish indicators raised the Criterion D status above the level set by hard coral cover in 16 of the 21 ecoregions, whereas the algae-coral ratio did not raise it in any. This result is in line with the relatively stable hard coral cover and persistently low macroalgal cover reported across East Asia (Kimura et al., 2026b). The most severe declines in both fish indicators occurred in the eastern Coral Triangle (Papua, Banda Sea, Lesser Sunda, Northeast Sulawesi, Gulf of Papua) and in the northern ecoregions along the Kuroshio Current and the southeastern Chinese coast (Central Kuroshio Current, South Kuroshio, East China Sea, Southern China). These patterns are consistent with the widespread overfishing reported across the region (Burke et al., 2011; Kimura et al., 2022). However, these results also partly reflect the baselines used. The grouper and parrotfish baselines from the Papua ecoregion stem from a single extraordinarily high-biomass no-take zone (Selat Dampier in Raja Ampat) which are by far the highest in the region. These baselines were then borrowed by five other ecoregions, including the Gulf of Papua, which may have led to an overestimation of risk statuses where reefs naturally support lower fish densities.

We acknowledge a few key limitations that may have influenced the outcomes of this assessment. Most importantly, the way in which fish baselines were retrieved differs from the approach used for most other regions. For instance, for several reference areas chosen, the monitoring data used to calculate baselines also includes survey years from before protection began (e.g. Amamigunto, protected in 2021 and surveyed since 2001). Given that fish populations need time to recover following the establishment of protected areas, the

inclusion of sampling points from earlier years likely lowered the fish baselines. Nevertheless, fish indicators still raised the Criterion D status despite including earlier surveys (e.g. South Kuroshio and Palawan/North Borneo to EN), suggesting that the risk of collapse was likely not substantially underestimated. Furthermore, most reference areas were multiple-use marine parks rather than strict no-take zones. While restricting the baselines to long-established no-take zones with at least 10 years of protection would have been preferable (Edgar et al., 2014), this approach would have substantially reduced the number of suitable reference sites with enough data in the region. The resulting lower baseline estimates likely make the estimated fish declines more conservative.

The compiled datasets used in this RLE assessment lacked coverage in several ecoregions assessed. For instance, even though we combined several different data sources, the final benthic dataset did not contain any record from the Gulf of Papua and Arafura Sea. In addition, the benthic monitoring time series were too short for Halmahera and the South China Sea Oceanic Islands to define hard coral baselines. Hence, these four ecoregions were Data Deficient (DD) under Criterion D, leaving around 13% of the mapped reef area without an assessment of biotic disruption. To improve future assessments of coral reefs in East Asia, it is crucial that long-term reef monitoring is expanded also in these remaining ecoregions.

The lower taxonomic resolution of the GCRMN dataset required the usage of Serranidae as a proxy for groupers (currently Epinephelidae) in eight countries. However, this broader family previously also included planktivorous fairy basslets and anthias (currently Anthiadidae), which are often found in large schools. This fact may partially explain why grouper baselines exceed parrotfish baselines in the Andaman Sea Coral Coast and the Gulf of Tonkin ecoregions. This is particularly relevant for ecoregions where baselines are derived from countries with different taxonomic resolutions. For instance, the Sunda Shelf/Java Sea baselines stem from marine parks in Malaysia where only groupers were recorded, while current values in this ecoregion and in the Malacca Strait include broader Serranidae counts from Indonesia and Singapore. This may explain why mean grouper densities in both ecoregions exceed their baselines, and suggests that grouper declines there are likely underestimated. It is important to note that by analyzing trends of fish densities, losses or gains may be over- or underestimated depending on the sizes of individuals. Because fishing is size-selective and large individuals are removed first, trends in parrotfish and grouper densities likely underestimate the change in herbivory and predation. To overcome this limitation, future iterations of these assessments would benefit from size-resolved data which would allow modelling trends in biomass.

Overall, East Asian coral reefs are already under considerable pressure and face a severe risk of collapse under projected ocean warming. However, the relatively stable coral cover (Kimura et al., 2026b) and lower observed heat stress in parts of the Coral Triangle and the Sunda Shelf may suggest that many reefs still retain the capacity to recover from disturbances such as bleaching. At the same time, the depletion of parrotfish and grouper stocks contributes to the erosion of key ecosystem functions such as herbivory and predation, hampering the recovery potential of East Asia's reef ecosystems. To preserve stable fish

populations, it is crucial to promote effective fisheries management and protected no-take areas to strengthen the near-term reef resilience. Yet, these important actions cannot offset the projected ocean warming without rapid global emission reductions (Hughes et al., 2017). In conclusion, we call for more efficient regional fisheries management, the expansion of effective protection under the Kunming-Montreal Global Biodiversity Framework (CBD, 2022) and urgent global climate mitigation measures in an attempt to effectively preserve East Asian coral reefs for future generations.

Supplementary Materials

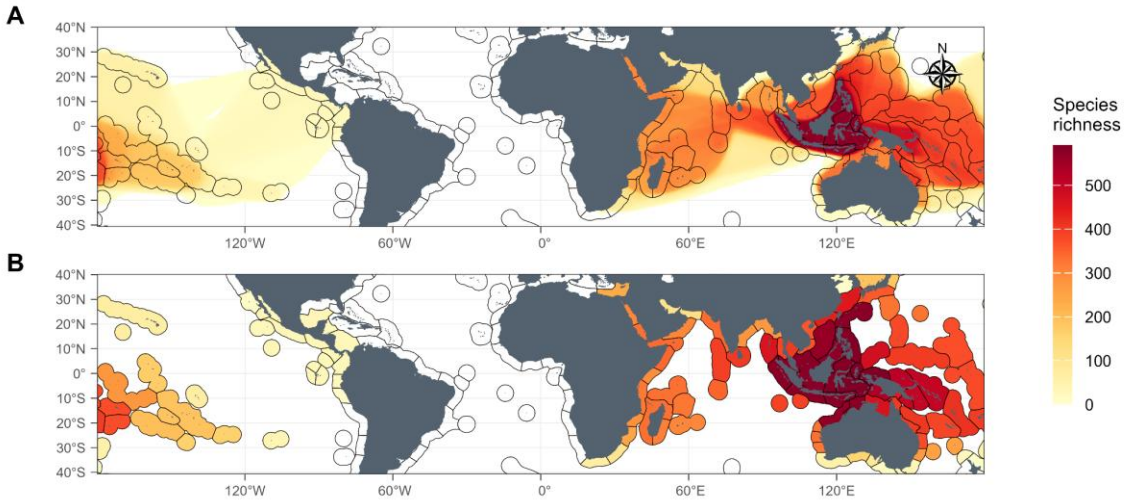


Figure S1 | Maps depict the global species richness of scleractinian corals mapped across 0.25° grid cells (A) and MEOW ecoregions (B; Spalding et al., 2007). Richness per unit reflects the total number of overlapping species ranges, based on range data from Veron et al. (2015). Both maps clearly delineate the Coral Triangle as the global epicenter of coral diversity, which is primarily located in East Asia.

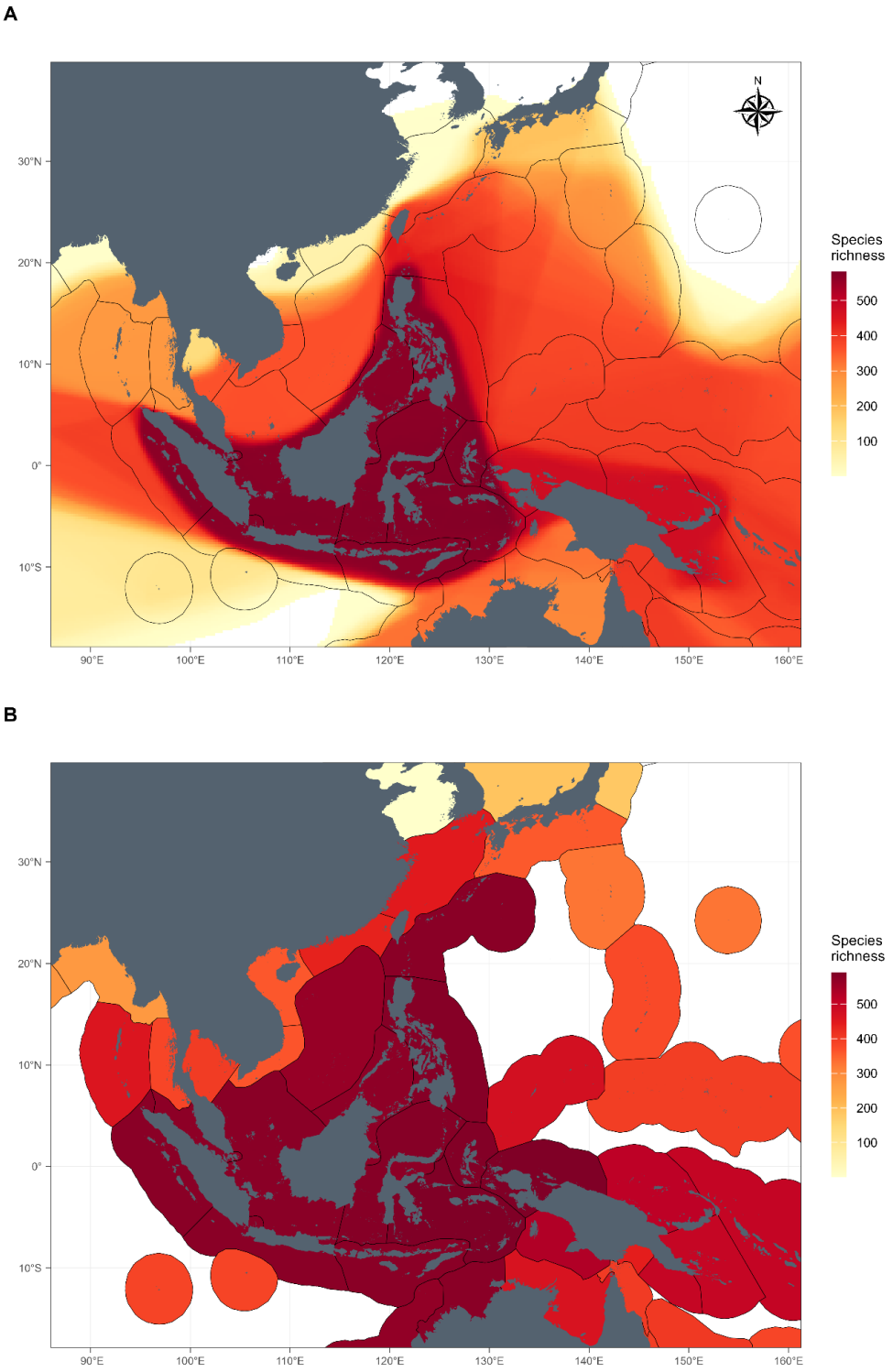


Figure S2 | Maps depict the species richness of scleractinian corals across the East Asian assessment area, mapped across 0.25° grid cells (A) and MEOW ecoregions (B; Spalding et al., 2007). Richness per unit reflects the total number of overlapping species ranges, based on range data from Veron et

al. (2015). Both maps clearly delineate the Coral Triangle as the global epicenter of coral diversity, which is primarily located in East Asia.

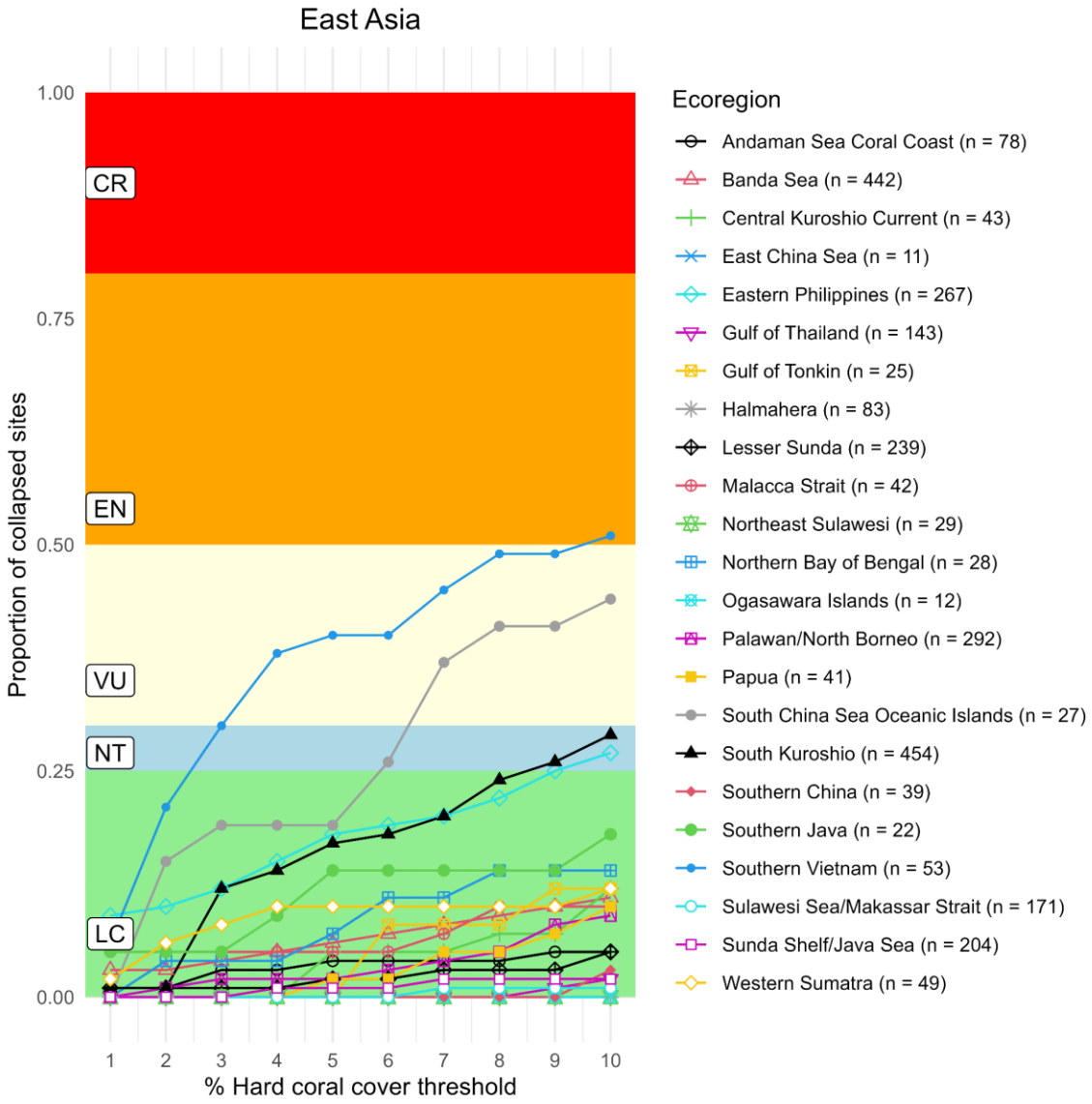


Figure S3 | Sensitivity sweep associated with the hard coral cover (HCC) threshold selection process for the evaluation of criterion A. For each ecoregion, the proportion of benthic study sites classified as collapsed is shown across candidate collapse thresholds of 1–10 % HCC. Shaded bands denote the corresponding IUCN RLE threat categories (LC, NT, VU, EN, CR). The number of benthic study sites used for each ecoregion are indicated in brackets.

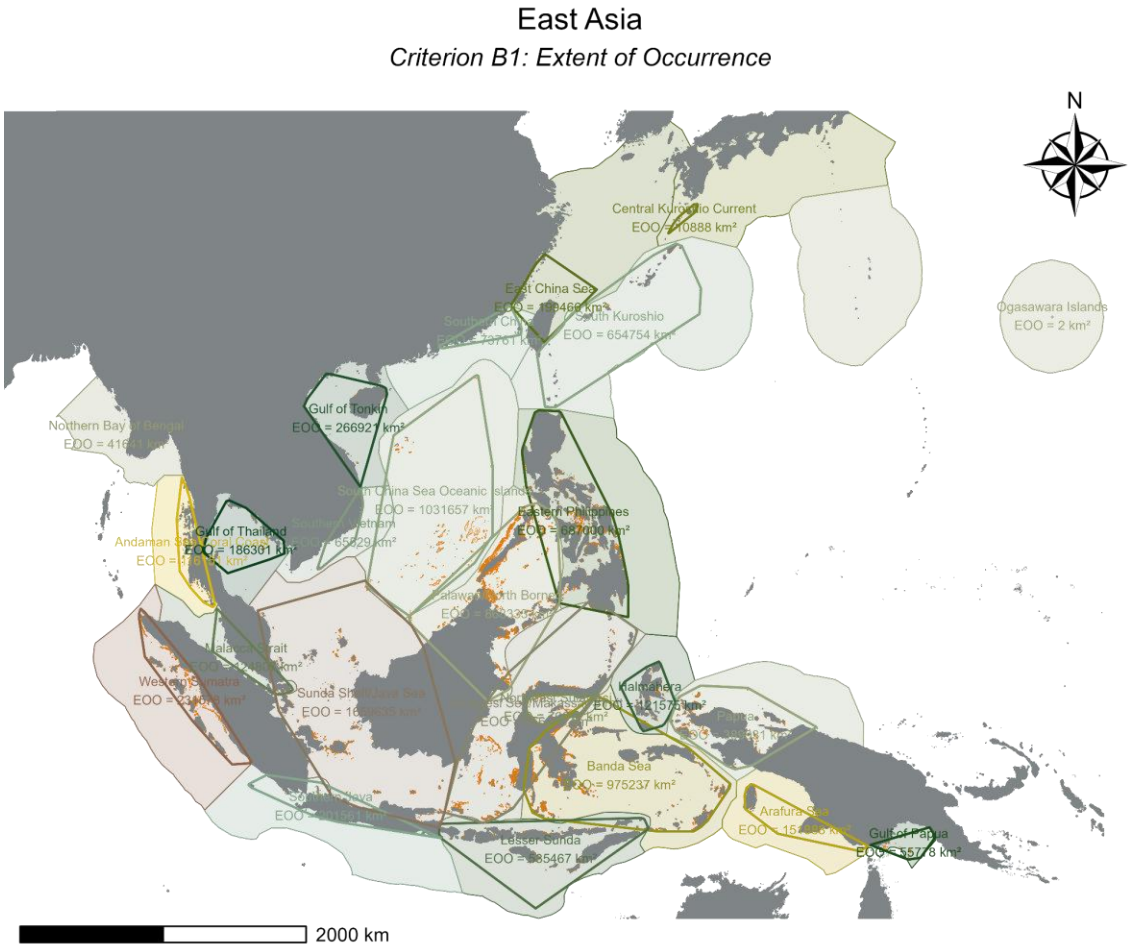


Figure S4 | Extent of occurrence (EOO) of coral reefs in each East Asian ecoregion evaluated under sub-criterion B1. The EOO was calculated as the area of the minimum convex polygon (outlines) enclosing all mapped coral reefs within each ecoregion. Reef extent is based on the Millennium Coral Reef layer, validated and adapted following feedback from regional experts. Labels show the EOO of each ecoregion in km^2.

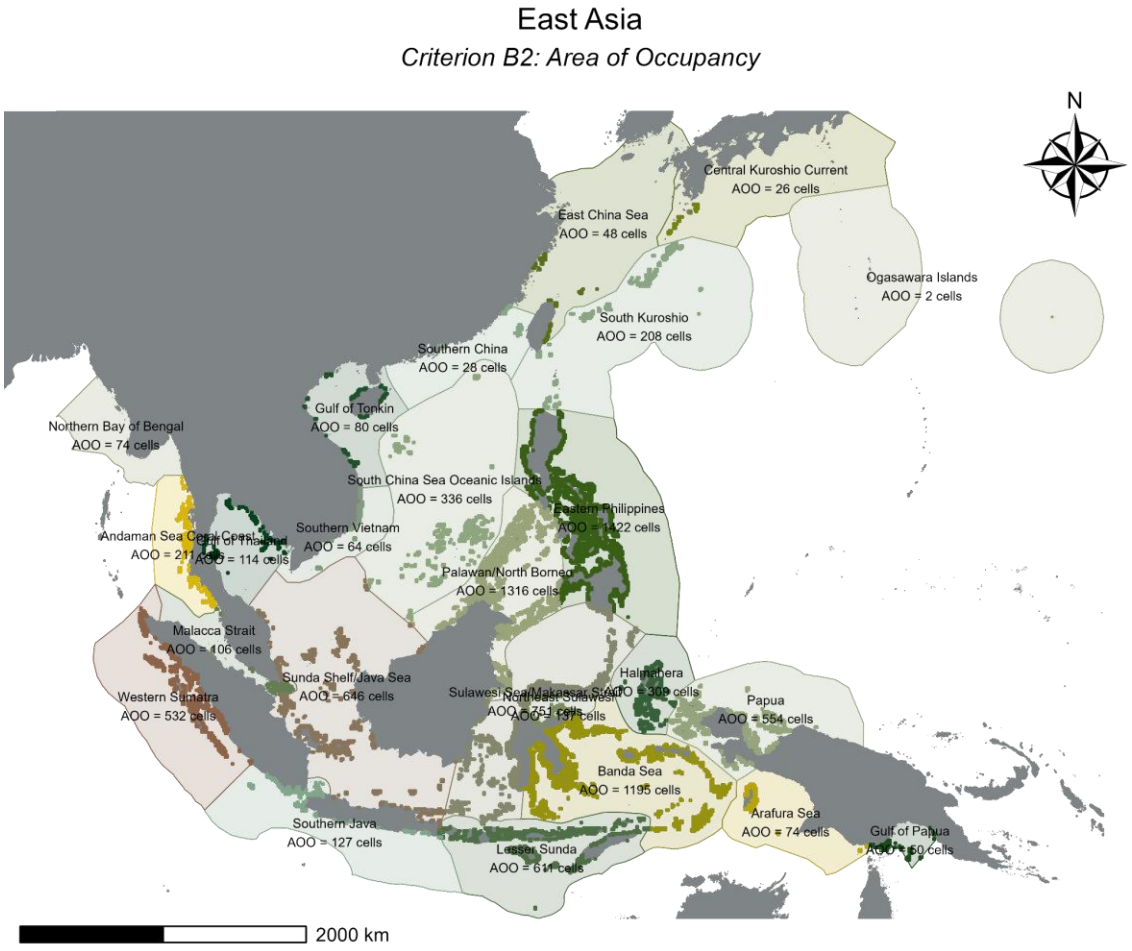


Figure S5 | Area of occupancy (AOO) of coral reefs in each East Asian ecoregion evaluated under sub-criterion B2. The grid cells (10 × 10 km) displayed contain mapped coral reefs within each ecoregion. Reef extent is based on the Millennium Coral Reef layer, validated by regional experts. Labels show the AOO as the number of occupied grid cells, counting only cells where reefs cover at least 1% of the cell area.

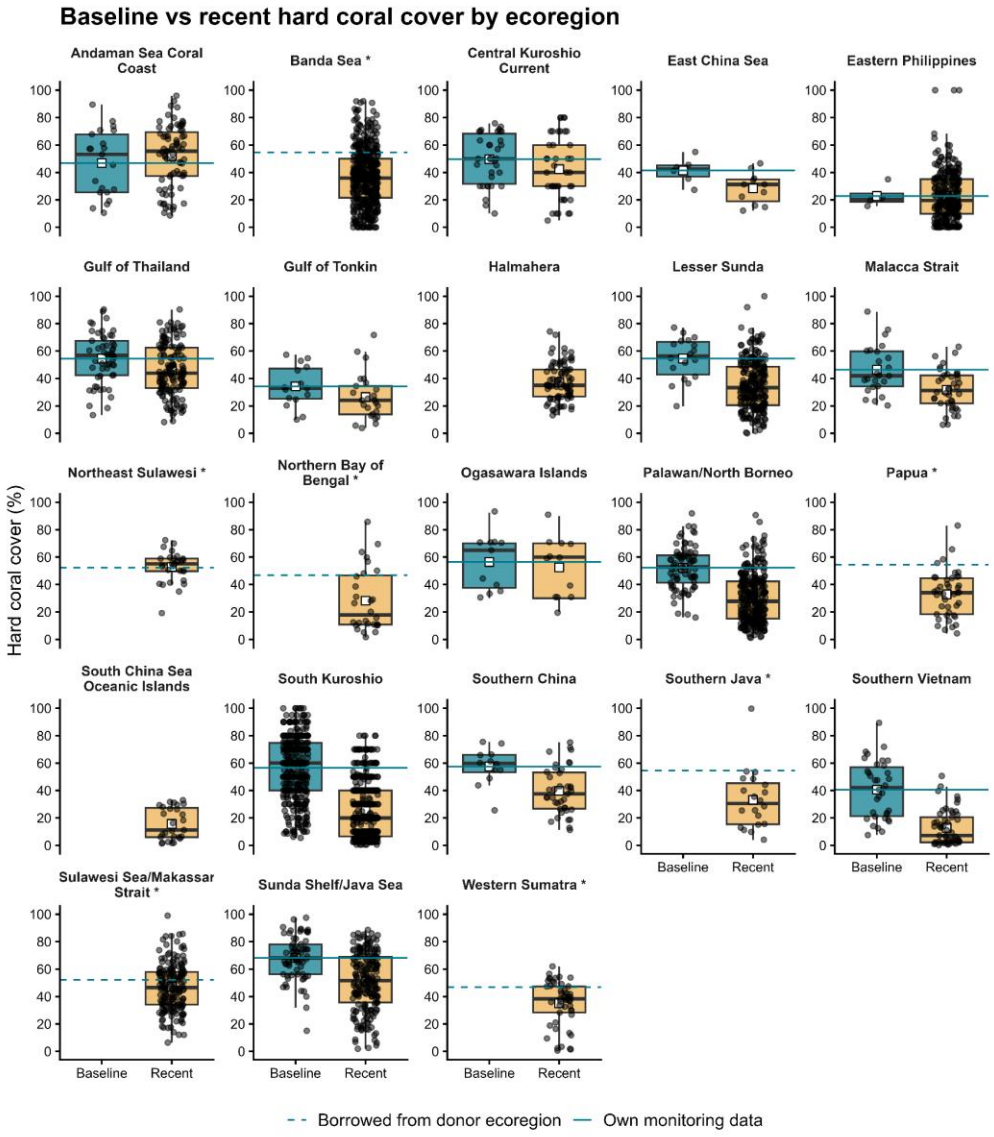


Figure S6 | Boxplots comparing baseline and recent hard coral cover (HCC) at monitoring sites in each East Asian ecoregion evaluated. The baselines correspond to the maximum HCC value on record, while recent corresponds to the mean of 2020–2025 surveys. Boxes show the interquartile range, white squares the mean, and points the individual sites. The teal line shows the ecoregion baseline mean used in the assessment. The dashed line and the asterisks indicate ecoregions with insufficient baseline data, for which the latter was borrowed from a donor ecoregion.

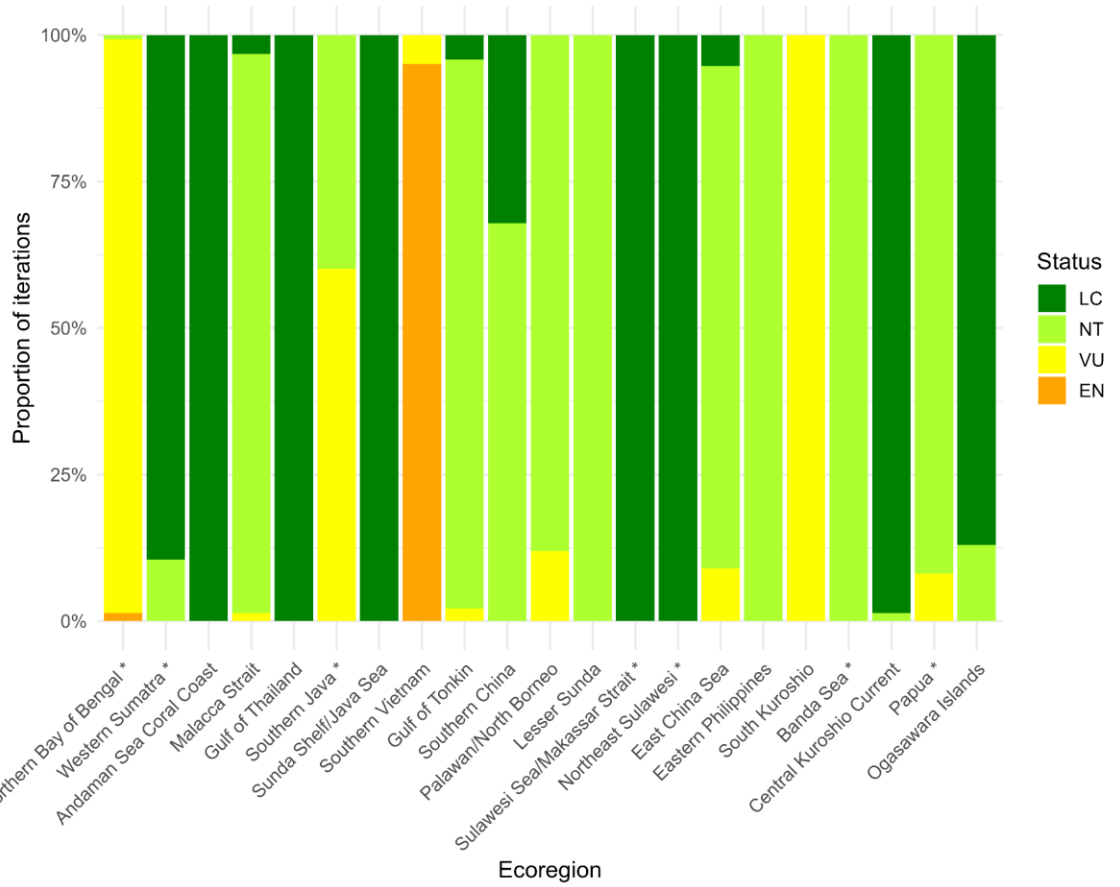


Figure S7 | Stacked barplots depict the risk status under Criterion D1 for hard coral cover, shown as the proportion of bootstrap iterations returning each status in every ecoregion evaluated. The final status assigned to each ecoregion is the plurality (modal) category. Ecoregions marked with an asterisk (*) borrow hard coral cover baselines from donor ecoregions as described in Annex 9.2.

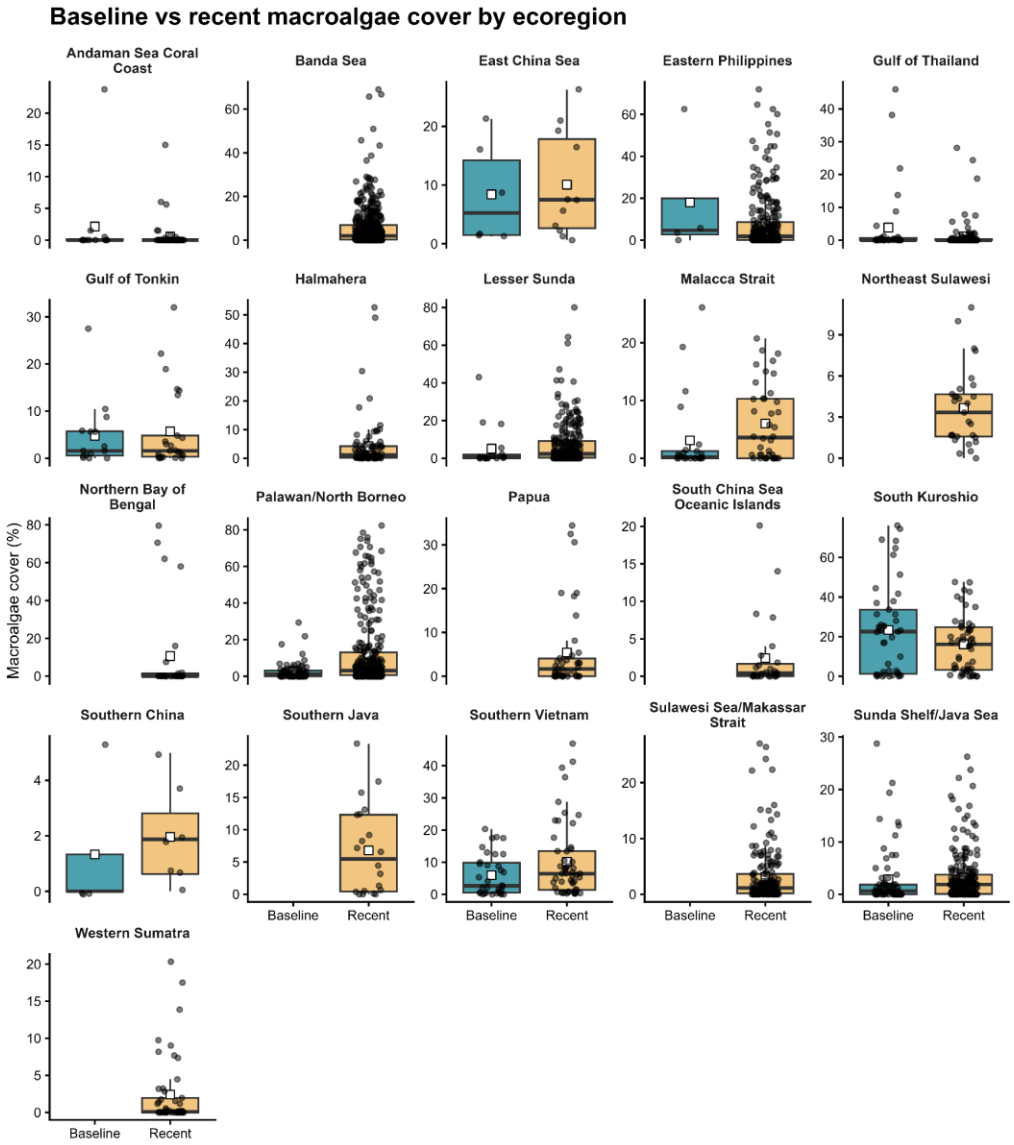


Figure S8 | Boxplots comparing baseline and recent macroalgal cover (MA) at monitoring sites in each East Asian ecoregion evaluated. The baselines correspond to the MA cover in the year where the maximum hard coral cover was recorded, while recent corresponds to the mean of 2020–2025 surveys. The dashed line depicts the collapse threshold of 0.833. Boxes show the interquartile range, white squares the mean, and points represent individual sites. No baselines were borrowed for this indicator; ecoregions without their own baseline were treated as Data Deficient.

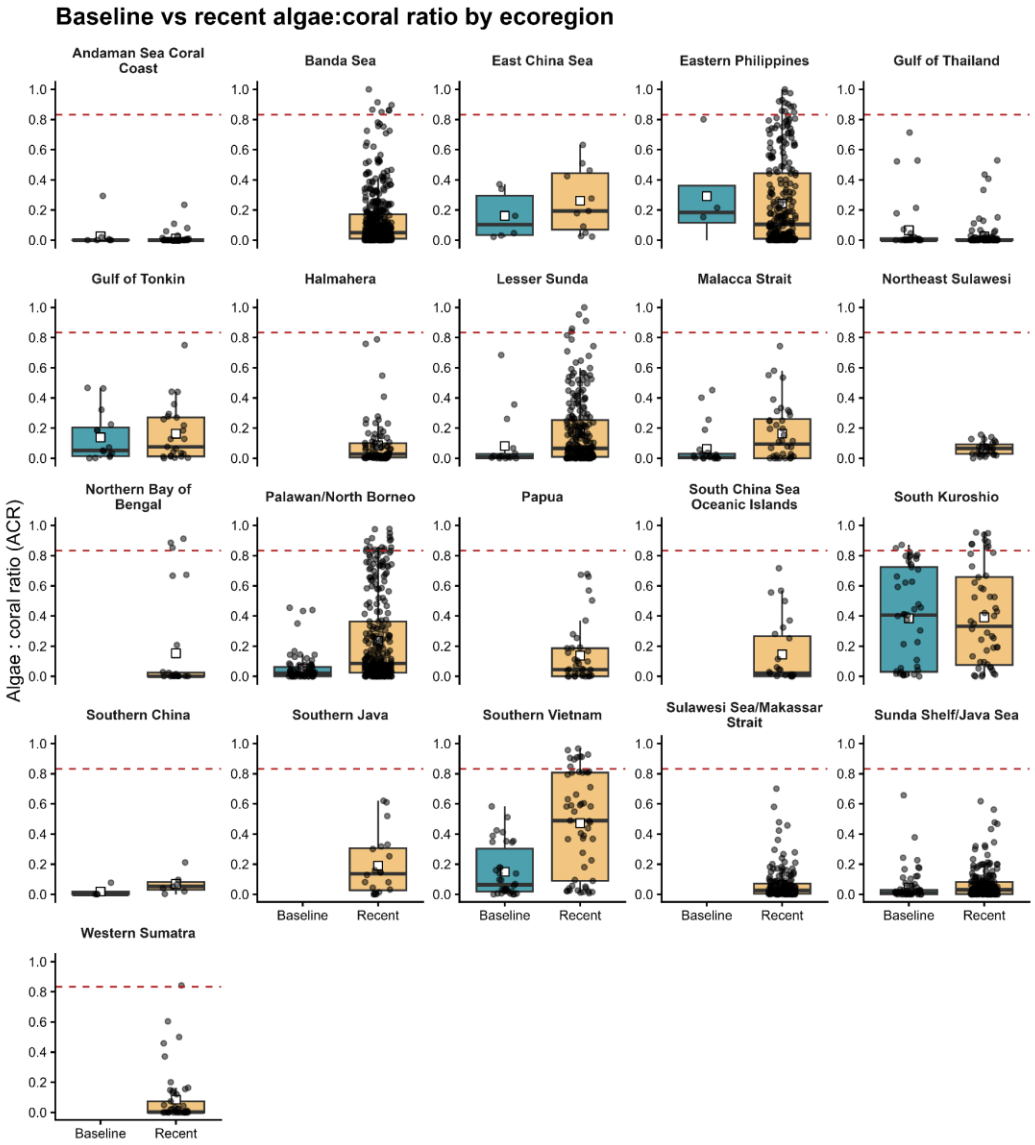


Figure S9 | Boxplots comparing baseline and recent algae/coral ratio (ACR) at monitoring sites in each East Asian ecoregion evaluated. The baselines correspond to the ACR in the year of maximum hard coral cover at each site, while recent corresponds to the mean of 2020–2025 surveys. Boxes show the interquartile range, white squares the mean, and points the individual sites. The red dashed line depicts the collapse threshold of 0.833, corresponding to algae cover being five times larger than hard coral cover (5:1). Ecoregions without baselines were not evaluated for this indicator (no borrowing scheme was implemented for ACR baselines).

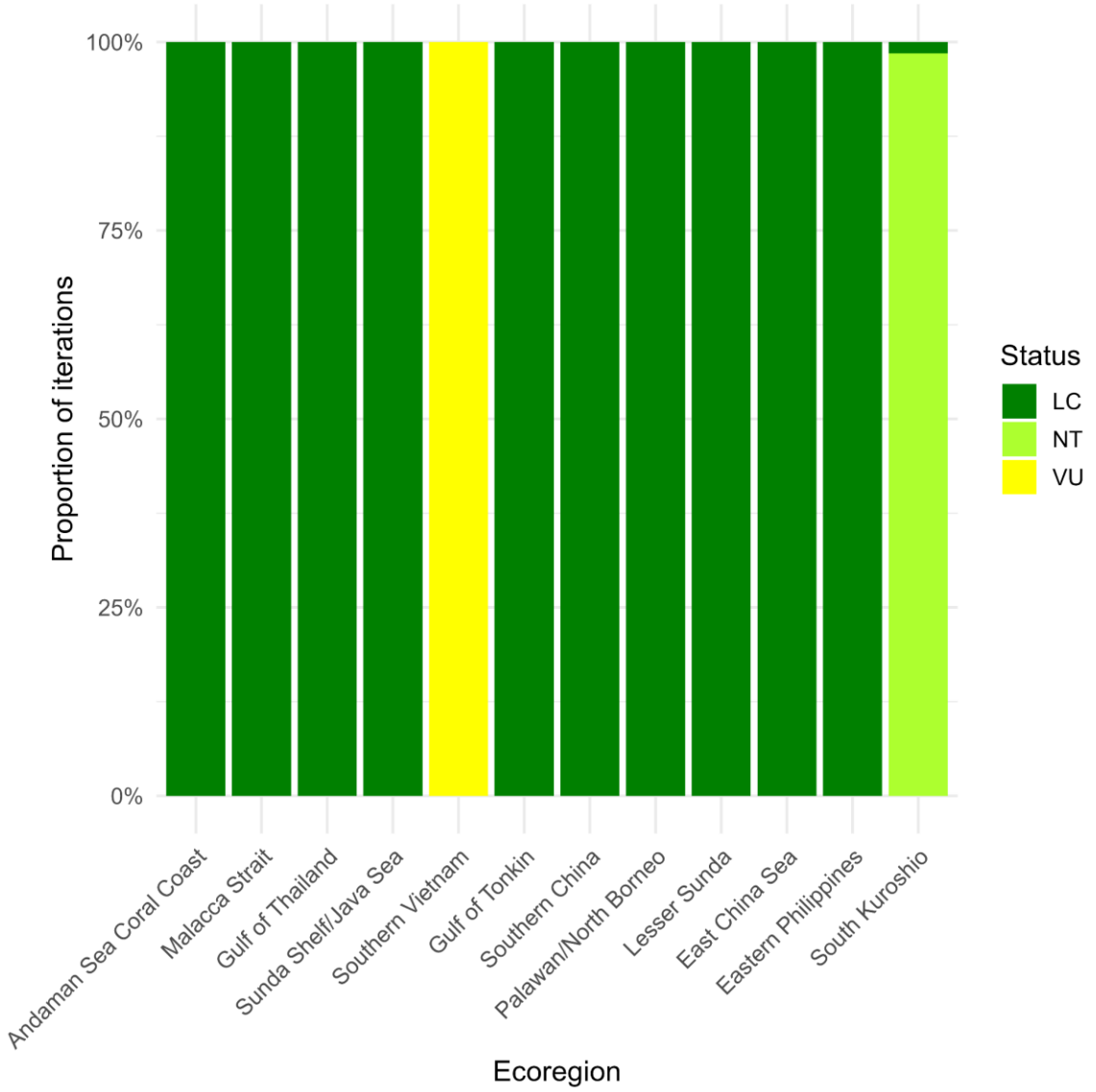


Figure S10 | Stacked barplots depict the risk status under Criterion D1 for the algae/coral ratio (ACR), shown as the proportion of bootstrap iterations returning each status in every ecoregion evaluated. The final status assigned to each ecoregion is the plurality (modal) category. Ecoregions without baselines were not evaluated for this indicator (no borrowing scheme was implemented for ACR baselines).

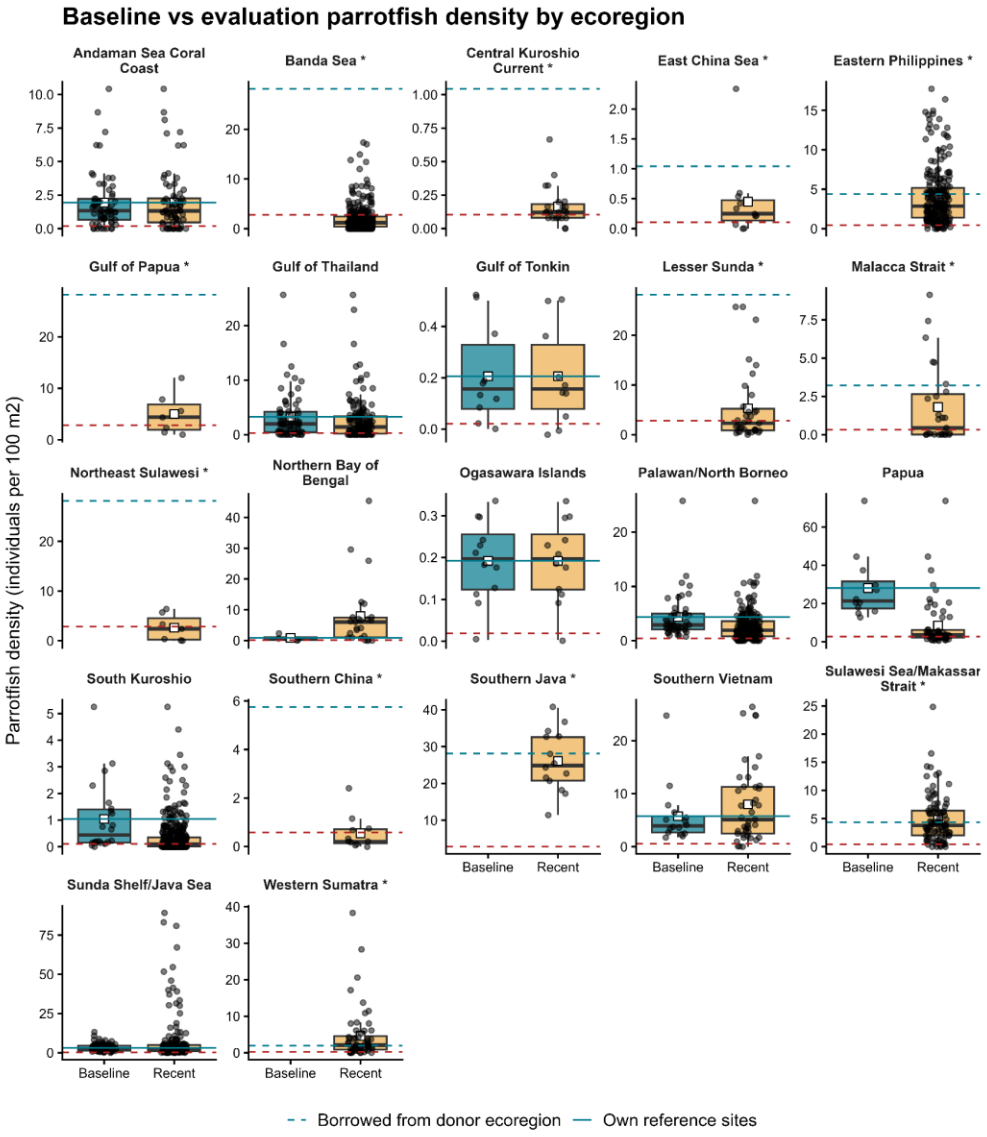


Figure S11 | Boxplots comparing baseline and current parrotfish (Scarinae) density at monitoring sites in each East Asian ecoregion evaluated. The baselines are derived by space-for-time substitution, taking the mean density at reference sites, while recent corresponds to the mean of 2020–2025 surveys. Boxes show the interquartile range, white squares the mean, and points the individual sites. The teal line shows the ecoregion baseline mean used in the assessment and the red dashed line the collapse threshold, set at 10% of the baseline. The dashed teal line and the asterisks indicate ecoregions without reference sites, for which the baseline was borrowed from a neighbouring donor ecoregion.

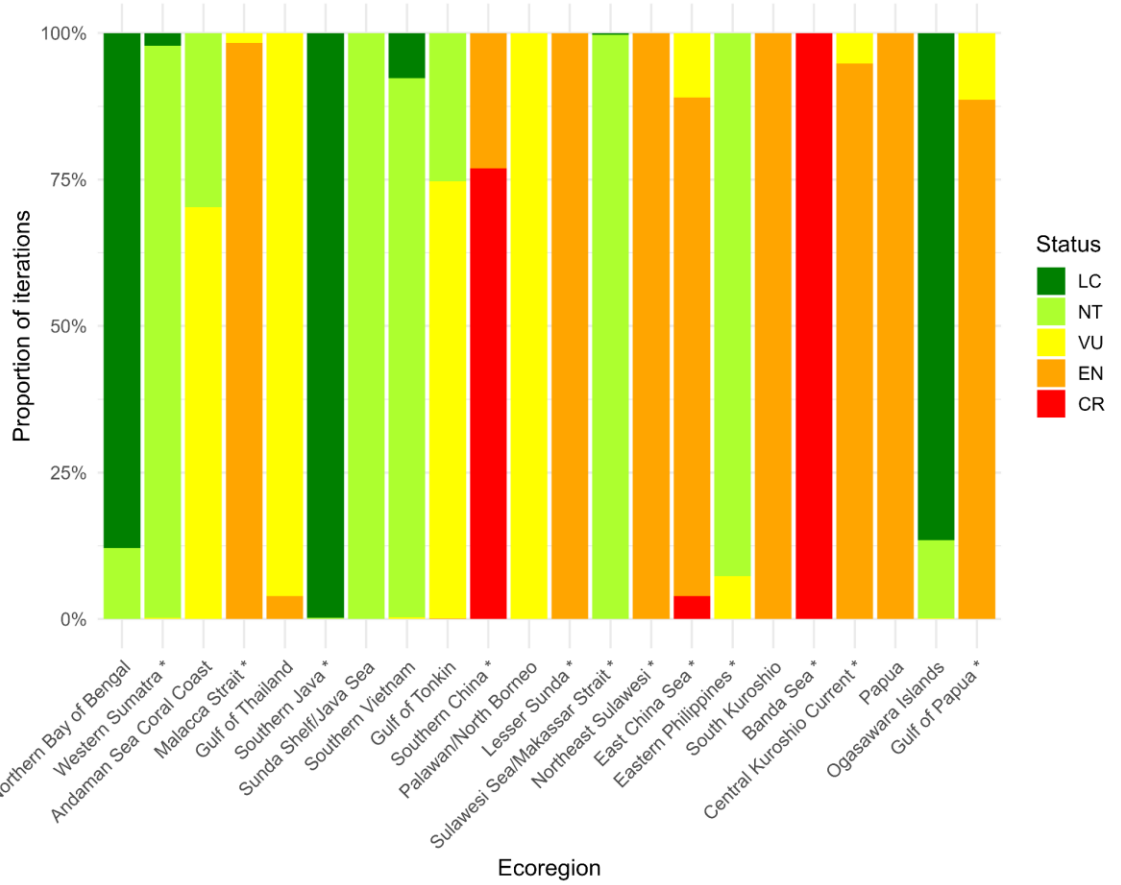


Figure S12 | Stacked barplots depict the risk status under Criterion D1 for parrotfish (Scarinae) density, shown as the proportion of bootstrap iterations returning each status in every ecoregion evaluated. The final status assigned to each ecoregion is the plurality (modal) category. Ecoregions marked with an asterisk (*) borrow parrotfish density baselines from donor ecoregions as described in Annex 9.2.

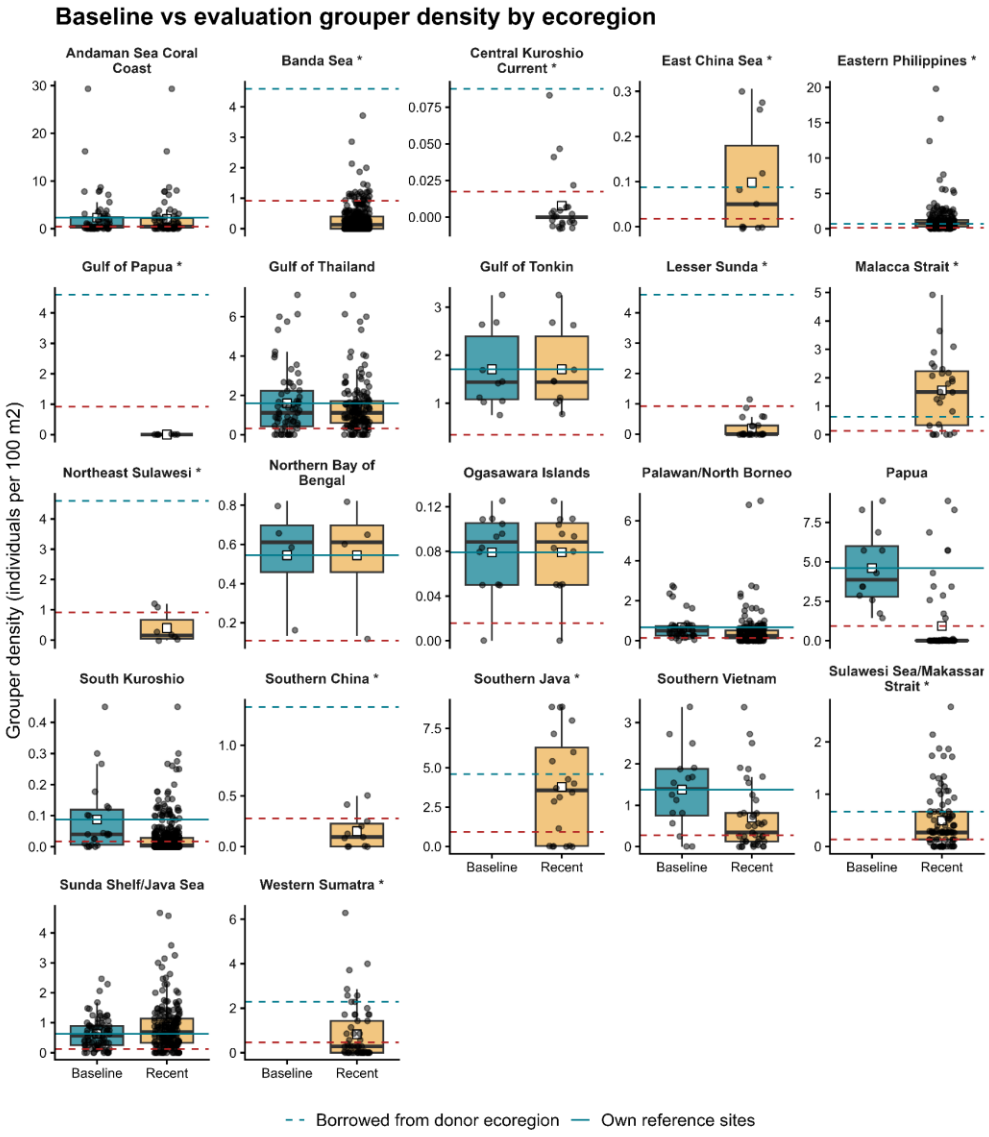


Figure S13 | Boxplots comparing baseline and current grouper (Epinephelidae or Serranidae depending on the data sources, see Annex 9.2) density at monitoring sites in each East Asian ecoregion evaluated. The baselines are derived by space-for-time substitution, taking the mean density at reference sites, while recent corresponds to the mean of 2020–2025 surveys. Boxes show the interquartile range, white squares the mean, and points the individual sites. The teal line shows the ecoregion baseline mean used in the assessment and the red dashed line the collapse threshold, set at 20% of the baseline. The dashed teal line and the asterisks indicate ecoregions without reference sites, for which the baseline was borrowed from a donor ecoregion.

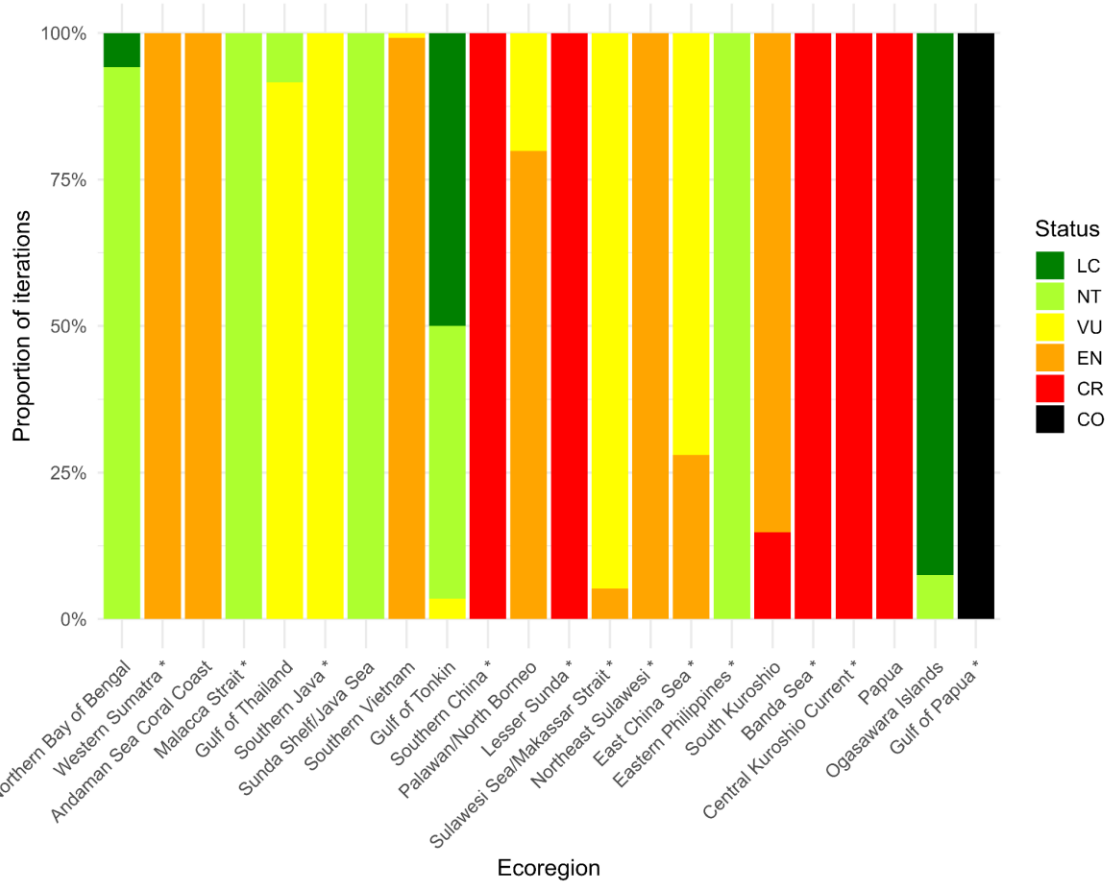


Figure S14 | Stacked barplots depict the risk status under Criterion D1 for grouper (Epinephelidae or Serranidae depending on the data sources, see Annex 9.2) density, shown as the proportion of bootstrap iterations returning each status in every ecoregion evaluated. The final status assigned to each ecoregion is the plurality (modal) category. Ecoregions marked with an asterisk (*) borrow grouper density baselines from donor ecoregions as described in Annex 9.2.

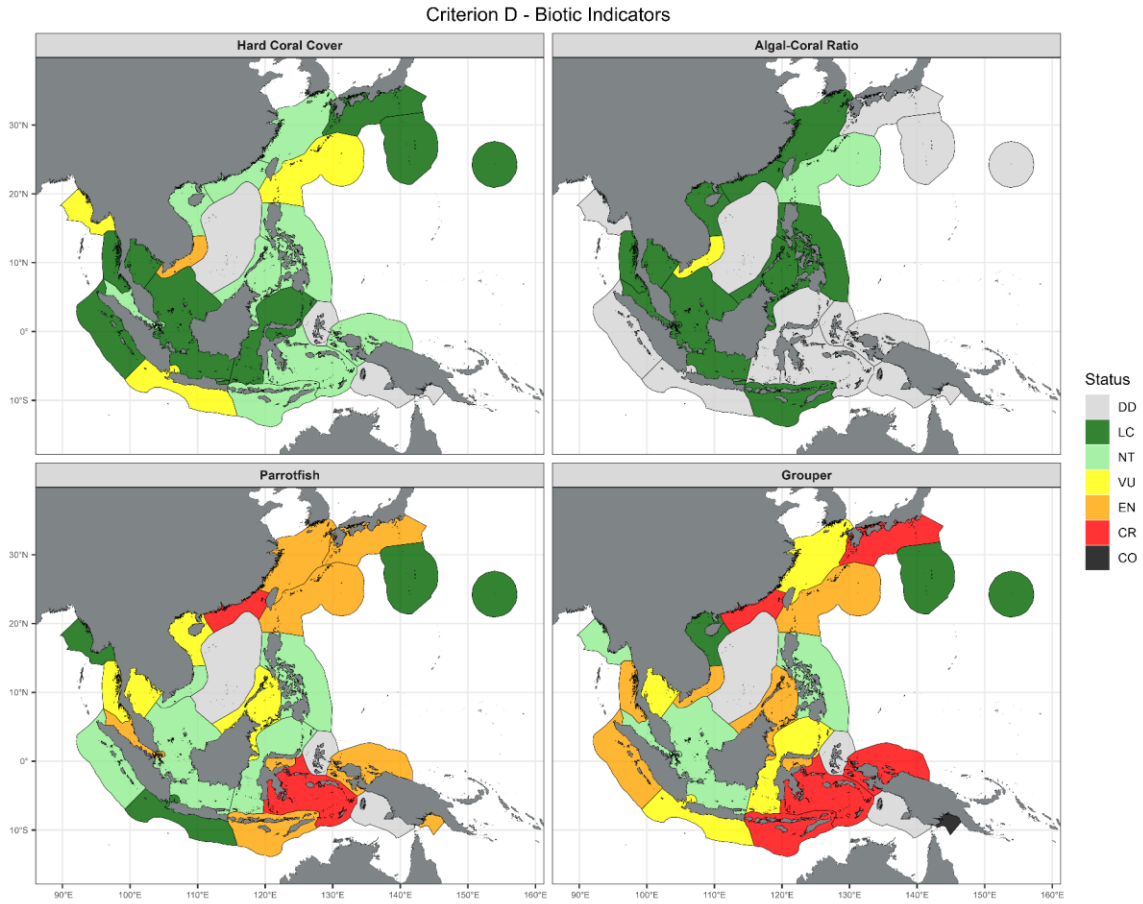


Figure S15 | Risk status of the four biotic indicators used in Criterion D: hard coral cover, algal-coral ratio, parrotfish and grouper. Ecoregions marked DD lacked sufficient data coverage for a given indicator.

Criterion C – Environmental Degradation: supplementary figures

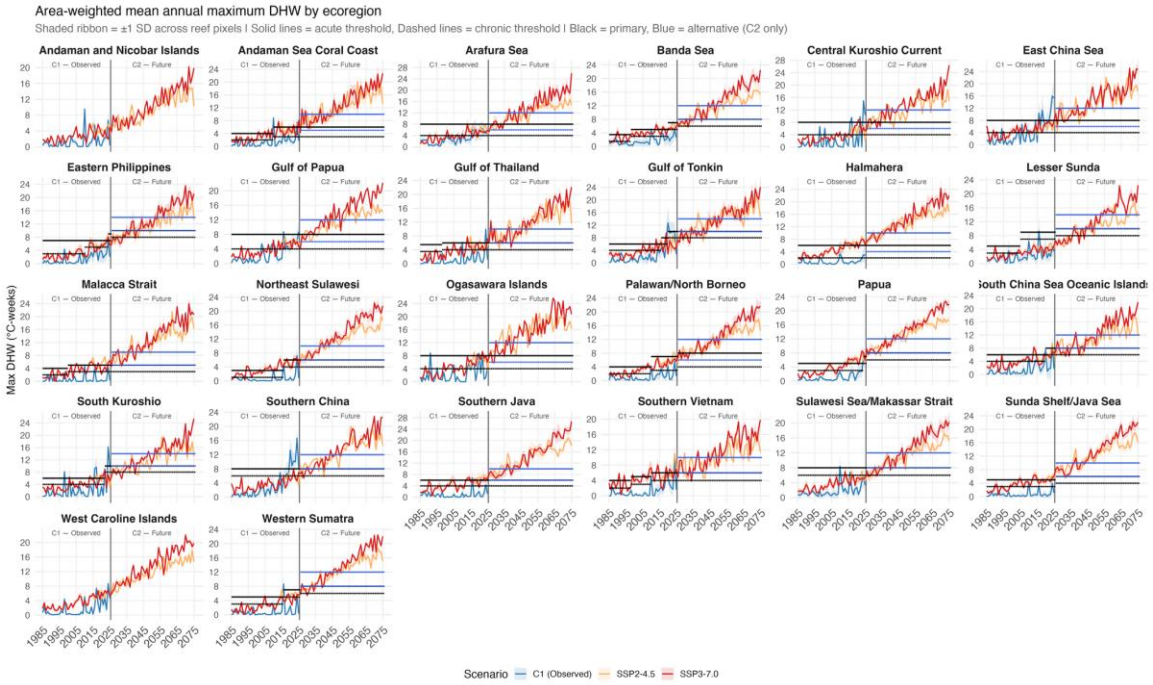


Figure S16. Annual maximum Degree Heating Weeks (DHW) averaged across coral reefs within each ecoregion from 1985-2075 for four trajectories: observed data used to assess sub-criterion C1 from 1985-2025 (blue line), and projections under three Shared Socioeconomic Pathways — SSP2-4.5 (orange), SSP3-7.0 (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 S17. 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.

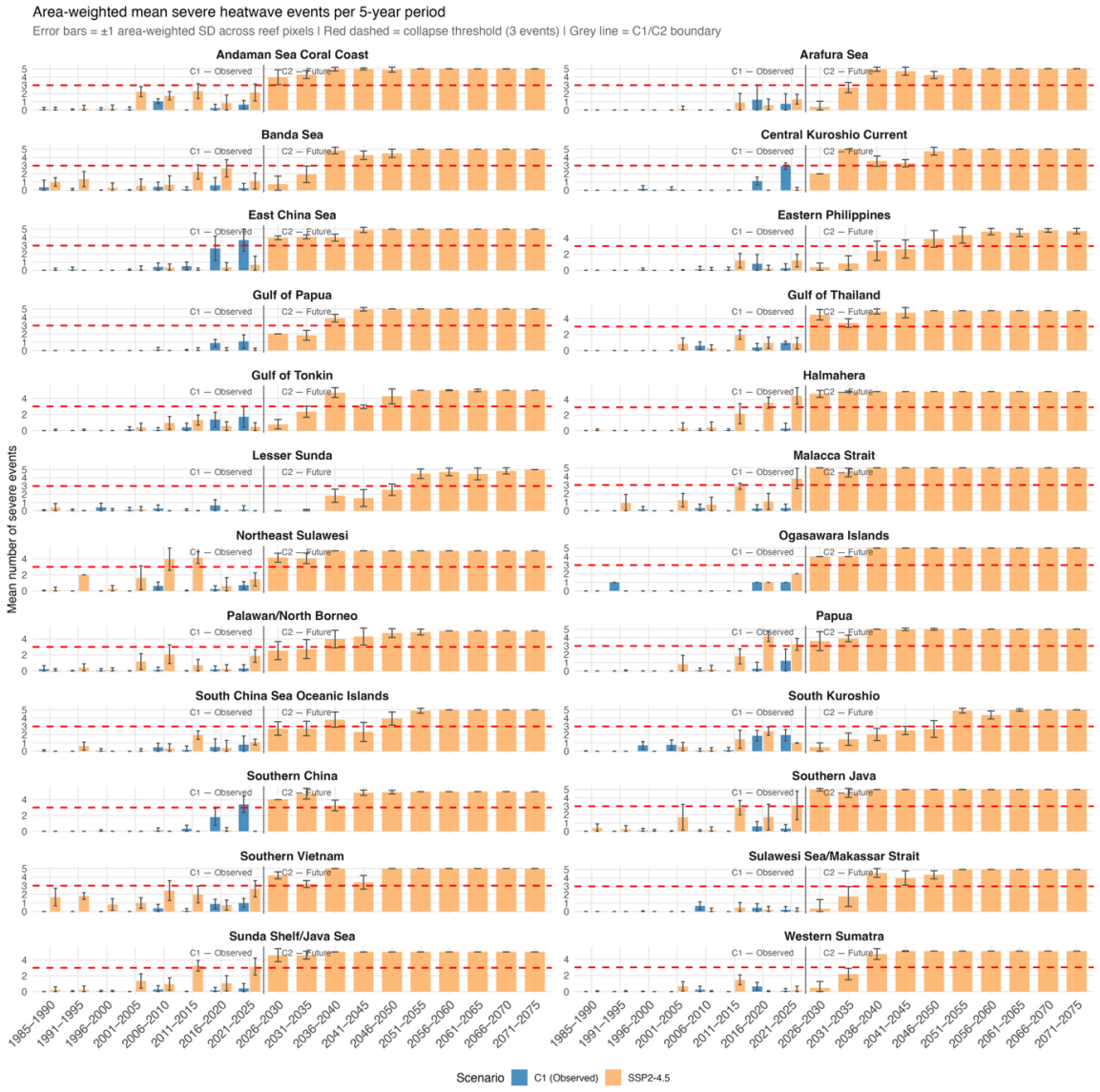


Figure S18. Mean number of severe mortality events per 5-year period, averaged across coral reef pixels within each ecoregion, under two trajectories: observed data used to assess sub-criterion C1 (blue bars, 1985–2025) and projections under SSP2-4.5 (orange bars, 1985–2075). Severe mortality events are defined as years in which annual maximum DHW exceeded ecoregion-specific acute stress thresholds associated with widespread coral mortality. Error bars represent ±1 SD across reef pixels within each ecoregion, reflecting spatial variability in the frequency of severe thermal exposure. The red dashed horizontal line indicates the collapse threshold of 3 severe mortality events within a 5-year window. The vertical grey line marks the boundary between the observed (C1, 1985–2025) and projected (C2, 2026–2075) assessment periods.

Appendices: Ecoregion Factsheets

1 - Central Kuroshio Current - Critically Endangered (CR)

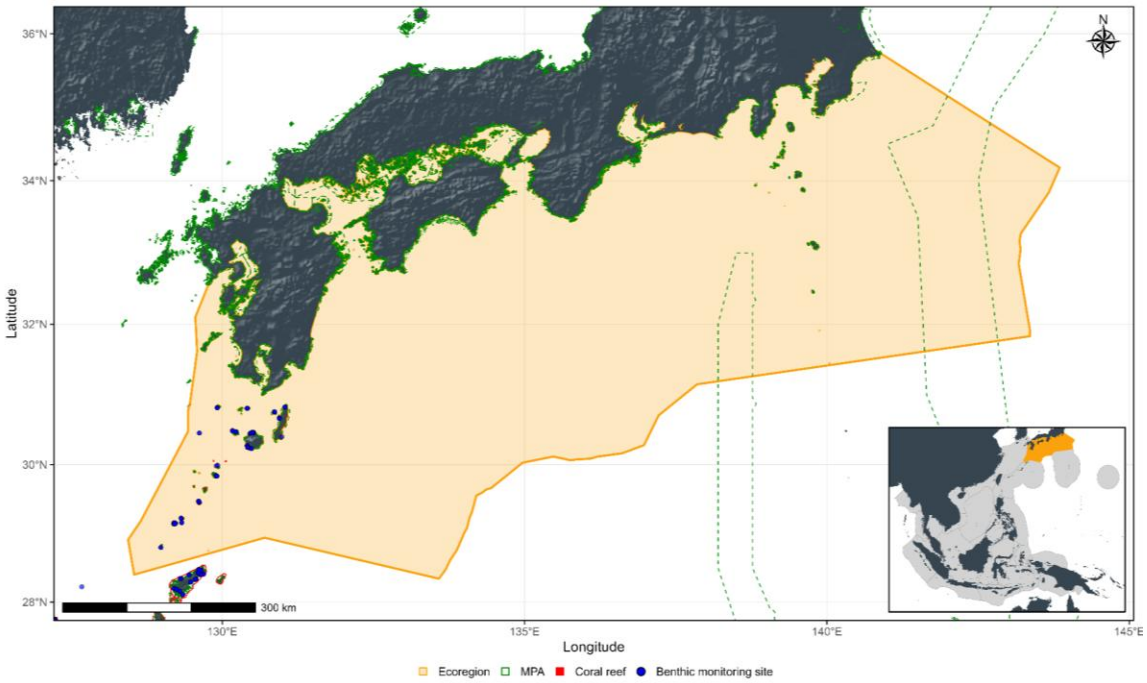


Figure 17 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Central Kuroshio Current ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Central Kuroshio Current coral reef ecoregion extends between 28.34°N and 35.81°N, 128.44°E and 143.85°E, and contains approximately 39.9 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). The area extends from the Tokara Archipelago, extending northwards along the southern and western coasts of Kyushu and further along the eastern coast of mainland Japan to Chiba Prefecture. The northern limit of coral reef development is located around Yakushima and Tanegashima in the Ryukyu Archipelago (Nakai & Nojima, 2004). Following feedback from GCRMN East Asia national coordinators, all higher-latitude sites (North of 31°N latitude) were excluded as non-reefal environments where corals grow on rocky substrata rather than on accreting coral reefs.

Ecosystem description

This ecoregion harbours approximately 359 scleractinian (hard) coral species (Veron et al., 2015). In the Tokara Archipelago, reef-building corals dominate and contribute to the development of coral reefs (Nakai & Nojima, 2004). However, towards higher latitudes, non-reefal coral communities on rocky substrates become increasingly dominant (Veron & Minchin, 1992). Further north on mainland Japan, reef systems are predominantly rocky

reefs (Veron & Minchin, 1992). Coral species composition also differs markedly between the Ryukyu Archipelago up to the Tokara Archipelago and the Yakushima-Tanegashima and Kyushu regions (Veron et al., 2015).

The Kuroshio Current is a key driver for observed patterns in reef (type) distributions and coral diversity. It flows northwards through the center of the Tokara Archipelago and rapidly deflects eastwards between the Tokara Archipelago and Yakushima (Nakai & Nojima, 2004), then continues northwards along the eastern coast of mainland Japan, reaching as far as the Chiba Prefecture (Kamachi et al., 2004). From the northern Ryukyus, the Tsushima Warm Current branches off westwards from the Kuroshio Current, allowing the existence of high latitude coral communities in southwestern Kyushu Island.

The decreasing influence of the Kuroshio Current at increasing latitude, corresponds to a northwards decline in coral species richness (Veron & Minchin, 1992). The Kuroshio Current also acts as a dispersal corridor for larvae, but it is also hypothesized to function as a biogeographic barrier between temperate and subtropical regions, restricting the movement of organisms from Yakushima southwards (Motomura & Matsuura, 2010).

Main threats faced by regional reefs include thermal related bleaching events, cold-water stress, destructive typhoons, and COTS outbreaks (Kimura et al., 2022).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
11.6%	10,888.33	21	Hard coral cover (%)	49.6	44.6
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	1.04 *	0.17
			Grouper density (ind. 100 m^{-2})	0.09 *	0.01

* Baselines for parrotfish and groupers borrowed from the South Kuroshio ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Central Kuroshio Current** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	EN	VU	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)
	VU	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Key findings:

- Overall status is Critically Endangered (CR) across all criteria, mainly driven by C1 and C2. Based on historical declines and present conditions alone (A, B, C1, D), the status is also CR.
- Criterion A is LC, with only 11.6% of sites below 10% hard coral cover. Criterion B is EN, reflecting the small reef extent at the northern limit of reef development in East Asia (EOO 10,888 km^2, AOO 21).
- C1 is CR, indicating frequent severe heat stress over the past 50 years.
- Criterion D is VU. While hard coral cover remained stable (49.6% to 44.6%), parrotfish (1.04 to 0.17 ind. 100 m^{-2}) and groupers (0.09 to 0.01 ind. 100 m^{-2}) are strongly depleted.

Recommendations:

- Reduce fishing pressure on parrotfish and groupers, for example through expanded no-take zones.
- Establish local fish reference sites to replace baselines borrowed from the South Kuroshio.
- Monitor bleaching alongside the poleward expansion of tropical species.

- Control COTS outbreaks

2 - East China Sea - Critically Endangered (CR)

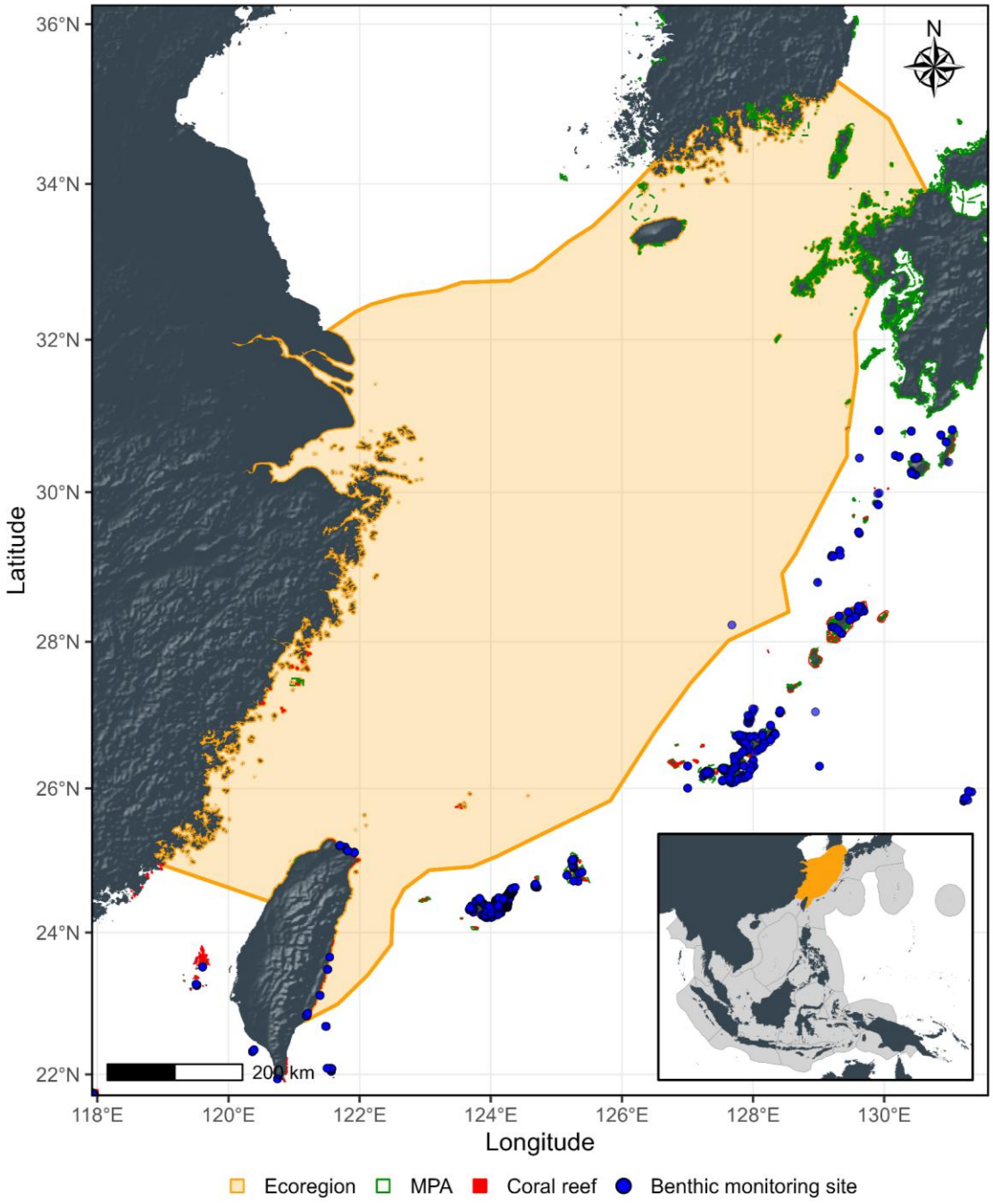


Figure 18 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the East China Sea ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The East China Sea coral reef ecoregion extends between 22.75°N and 35.31°N, 118.85°E and 130.65°E, and contains approximately 102.2 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). It harbours 448 scleractinian (hard) coral species.

The area extends from the southeastern coast of Taiwan through the east coast of China to Jeju Island, South Korea, as well as the Iki, Tsushima, and Goto Islands, Japan. Following feedback from GCRMN East Asia national coordinators, all records from South Korea were excluded as non-reefal environments where corals grow on rocky substrata rather than on accreting coral reefs.

Ecosystem description

This ecoregion harbours approximately 448 scleractinian (hard) coral species (Veron et al., 2015). The diversity of scleractinian corals decreases, while macroalgal diversity increases with increasing latitude (Ribas-Deulofeu et al., 2016). Reefs can be generalised as belonging to one of three areas at increasing latitudes: (1) Reefs in eastern and northern Taiwan considered as marginal (Ribas-Deulofeu et al., 2016), (2) Reefs around Jeju Island characterized by rocky reef systems (Ribas-Deulofeu et al., 2023) historically dominated by macroalgal communities (Kang, 2010) and diverse soft coral assemblages (Kim & Kang, 2022) but increasingly colonized by five reef-building coral species in recent years (Perrois et al., 2024; Jöst et al., 2025), and (3) Reefs in the Iki, Tsushima, and Goto Islands, where approximately 40 species of reef-building corals have been recorded (Yamano et al., 2004). The coral reefs at Kurosaki in the Iki Islands are also recognized as among the northernmost coral reefs in the world (Yamano et al., 2001).

Temperature is a major environmental constraint on coral distribution and reef development across the East China Sea ecoregion, particularly towards its high-latitude margins. Low winter temperatures limit coral survival and reef accretion across many sites, whereas the poleward transport of the Kuroshio Current reduces this thermal constraint. For example, winter SST falls below 18 °C, limiting reef accretion and favouring non-reefal coral communities in northern Taiwan (Ribas-Deulofeu et al., 2016). Farther north, winter temperatures can decline to approximately 13 °C around Iki and Tsushima, and to around 12–14 °C around Jeju Island.

The Tsushima Warm Current, a warm and saline surface branch of the Kuroshio Current, transports warm water northwards through the East China Sea and strongly influences southern Jeju Island, particularly during summer (Yamano et al., 2004; Perrois et al., 2024). This warm-current influence facilitates the persistence and ongoing poleward expansion of subtropical coral communities at high latitudes (Kim & Kang 2022; Jöst et al., 2025). However, increasingly high summer temperatures and marine heatwaves can also expose these marginal coral communities to acute thermal stress and bleaching (Kim et al., 2022; Jöst & Kim 2026). In addition, other important regional pressures include strong typhoons, high sedimentation, and nutrient enrichment (Liu et al., 2012).

Tropicalisation is increasingly evident across the East China Sea and adjacent marginal seas, where ocean warming is facilitating the poleward expansion of warm-water species and altering temperate marine communities. Evidence of these changes includes shifts in high-latitude coral assemblages along the Chinese coast and northern South China Sea (Yang et al., 2023; Wang et al., 2023), rapid poleward expansion of tropical reef corals and fishes in Japan (Yamano et al., 2011), and transitions from macroalgal- towards hard coral-dominated habitats in parts of Jeju Island, South Korea (Perrois et al., 2024). Together, these observations indicate a broader reorganization of benthic communities across the tropical–temperate transition zone.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
0%	199,466.41	39	Hard coral cover (%)	41.4	26.8
			Algae : coral ratio	0.16	0.29
			Parrotfish density (ind. 100 m^{-2})	1.04 *	0.45
			Grouper density (ind. 100 m^{-2})	0.09 *	0.1

* Baselines for parrotfish and groupers borrowed from the South Kuroshio ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the **East China Sea** was assessed as **Critically Endangered (CR).** Summary of the assessment:

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

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	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		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, driven by C1 and C2. Based on historical declines and present conditions alone, the status is also CR.
- Criterion A is LC, with no site below 10% hard coral cover. Criterion B is VU due to the small area of occupancy of marginal reefs (AOO 39).
- C1 is CR.
- Criterion D is VU. Hard coral cover declined from 41.4% to 26.8% (NT) and parrotfish from 1.04 to 0.45 ind. 100 m^{-2} (EN). Mean grouper density is close to the borrowed baseline but declined at individual sites (VU).

Recommendations:

- Reduce sedimentation and nutrient inputs.
- Monitor bleaching and tropicalisation at the northernmost reefs, such as in the Iki Islands.
- Develop local fish baselines to replace those borrowed from the South Kuroshio.

3 - Northern Bay of Bengal (Myanmar) - Critically Endangered (CR)

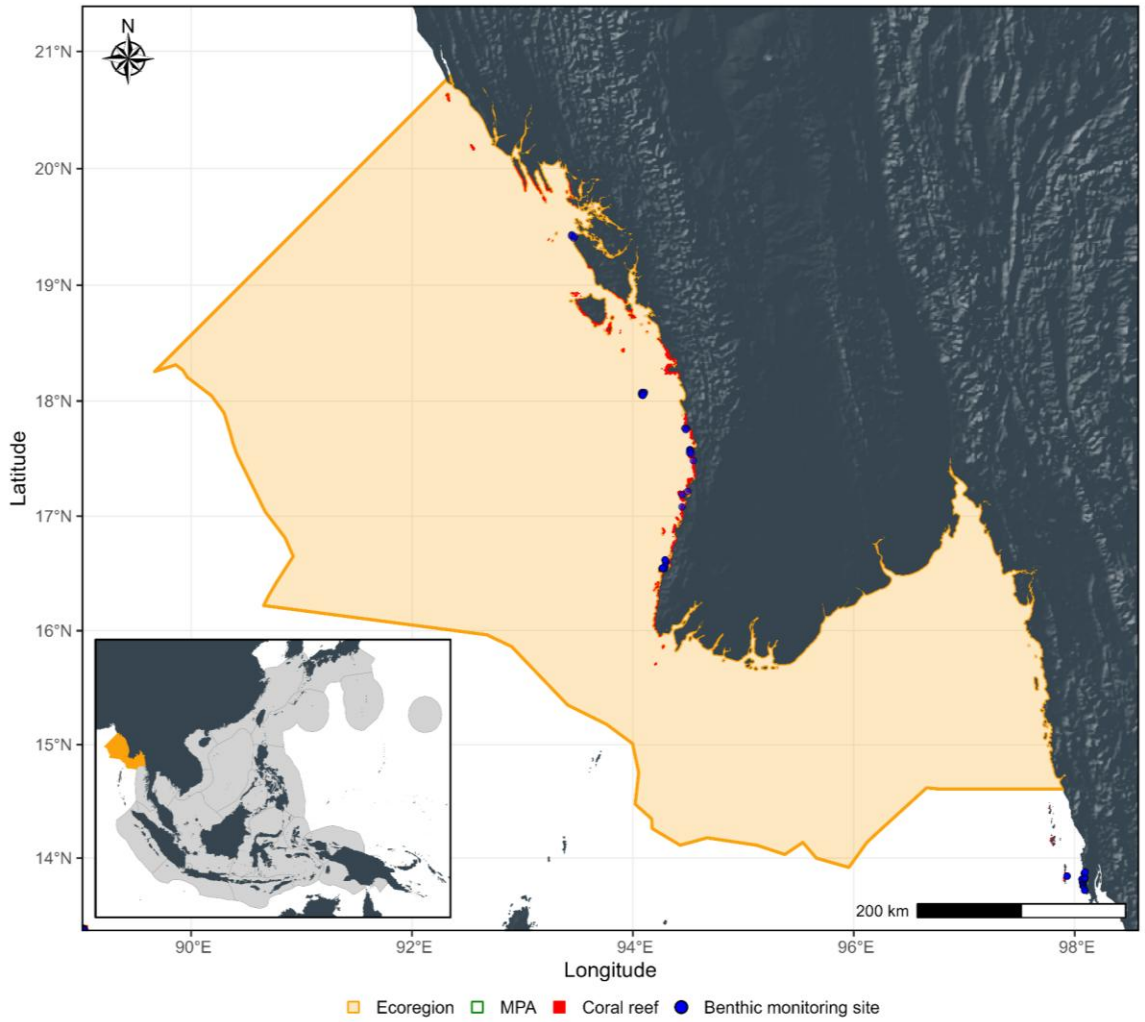


Figure 19 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Northern Bay of Bengal (Myanmar) ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Northern Bay of Bengal (Myanmar) coral reef ecoregion extends from 13.92°N to 20.85°N and 89.67°E to 97.92°E, and contains approximately 372.3 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). It harbours 268 scleractinian (hard) coral species (Veron et al., 2015). This ecoregion extends from the Rakhine coast of Myanmar, across the Ayeyarwady delta to the Gulf of Martaban. For this assessment, the Northern Bay of Bengal was cut at the border along the coast between Myanmar and Bangladesh, as the remaining northwestern part of this ecoregion is evaluated in the South Asia regional RLE report.

Ecosystem description

Reefs along the mainland Rakhine Coast are typically fringing and less developed, and reefs along the southern Mawdin Coast are noted to be rocky reefs, not true accreting reefs.

Nearshore hard coral cover varies from 9 to 69 %, with relatively low diversity. Offshore islands like the Munaung and Ramree Islands host some fringing reefs, which are typically in better condition (Murray-Jones et al., 2017). This pattern is presumably due to the high degree of terrigenous sediment originating from high volumes of river discharge, and high resuspension rates, resulting in chronic turbidity (Ramaswamy et al, 2004). Fishery activity is predominantly artisanal (Akester, 2019), but fisheries depletion is severe, with a shift in extraction patterns from high-value to high-replacement fish species (Akester, 2019). Hookah fishing has also been identified as a threat to reefs (Kimura et al., 2022).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
14.3%	41,641	74	Hard coral cover (%)	46.8 *	28.2
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	0.83	7.91
			Grouper density (ind. 100 m^{-2})	0.54	0.54

* Baselines for hard coral borrowed from the Andaman Sea Coral Coast ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the **Northern Bay of Bengal (Myanmar)** was assessed as **Critically Endangered (CR).** Summary of the assessment:

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

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

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

Key findings and recommendations

Key findings:

- Overall status CR across all criteria, driven by the risk due to projected ocean warming (C2). Based on historical declines and present conditions alone, the status is EN, driven by C1.
- Criterion A is LC (14.3% of sites below 10%). Criterion B is VU due to the limited extent of occurrence of coral reefs (EOO 41,641 km^2).
- C1 is EN.
- Criterion D is VU, driven by hard coral cover declining from 46.8% (baseline borrowed from the Andaman Sea Coral Coast ecoregion) to 28.2%. Parrotfish (LC) and groupers (NT) show no clear decline.

Recommendations:

- Expand benthic and fish monitoring along the Rakhine coast and the Gulf of Martaban.
- Address overfishing, prohibit hookah fishing and reduce sedimentation affecting nearshore reefs.

4 - Andaman Sea Coral Coast - Critically Endangered (CR)

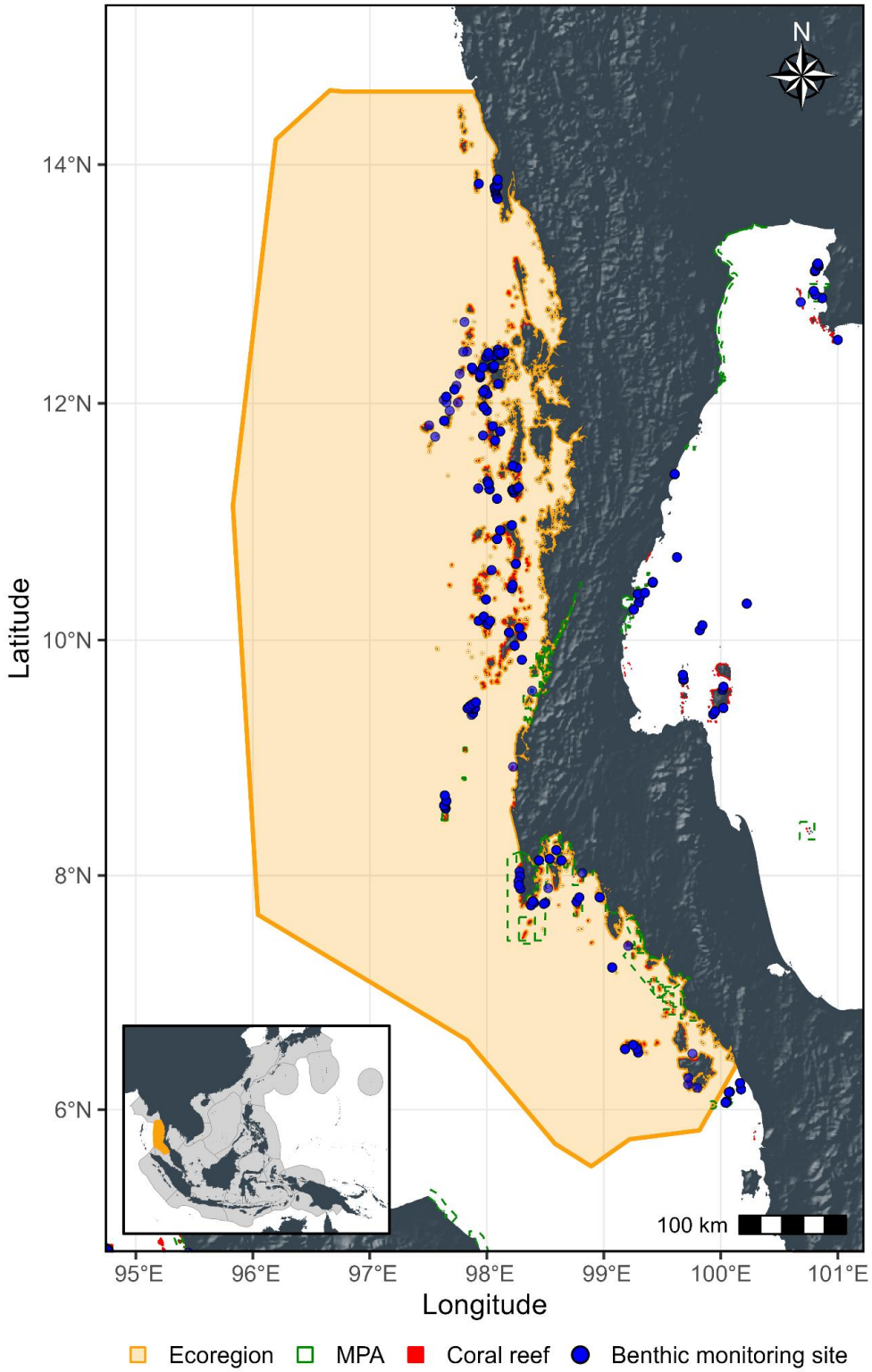


Figure 20 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Andaman Sea Coral Coast ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Andaman Sea Coral Coast coral reef ecoregion extends between 5.52°N and 14.62°N, 95.83°E and 100.13°E, and contains approximately 137.6 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). The eastern boundary begins along the western coast of Thailand and includes Phuket, and extends northwards beyond the northern boundary of the Mergui Archipelago. The southern border deflects northwards and does not include Aceh (the northern point of Sumatra), and the western boundary is roughly equidistant between Myanmar/Thailand and the Andaman and Nicobar Islands.

Ecosystem description

This ecoregion harbours approximately 385 scleractinian (hard) coral species (Veron et al., 2015). The majority of reefs in this ecoregion are fringing, inshore reefs, which are intertidal. Waters are more turbid than reefs in the adjacent Andaman and Nicobar Islands ecoregion (Brown, 2007).

The Indian Ocean Dipole (IOD) is a key abiotic driver of coral reef condition, and a major source of natural disturbance, most notably by altering sea levels and tide windows. As many reefs are intertidal, lowered sea levels and/or shifting tides may increase or alter exposure of reefs to solar radiation (Brown, 2007).

Notably, the 2004 earthquake and tsunami events which heavily impacted the neighboring Andaman and Nicobar Islands had minimal impact based on reports from western Thailand (Brown, 2007) and northwest Peninsular Malaysia (Lee et al., 2005).

Anthropogenic disturbances to reefs are noted to be limited, and most described threats are from the western coast of Thailand due to limited research occurring elsewhere. Some localised threats are dredging and processing of tin, land reclamation and dredging, and tourism-related activities. Climate warming remains the largest and most systemic threat to reefs, as there is a consistent record of increasing average temperatures in the Andaman Sea over the last five decades (at least 0.126 °C per decade) (Brown, 2007; Brown et al., 1996).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
5.1%	116,150.59	167	Hard coral cover (%)	46.8	51.9
			Algae : coral ratio	0.03	0.01
			Parrotfish density (ind. 100 m^{-2})	1.93	1.95

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
			Grouper density (ind. 100 m^{-2})	2.3	2.07

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Andaman Sea Coral Coast** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	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		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, driven by C2. Based on historical declines and present conditions alone, the status is VU, driven by C1 and D.
- Criterion A is LC (5.1%). Criterion B is LC.
- C1 is VU.

- Criterion D is VU. Hard coral cover (46.8% to 51.9%) and the algae-coral ratio remained relatively stable. Mean fish densities are close to baseline, but declines at individual sites classified parrotfish as VU and groupers as EN.

Recommendations:

- Strengthen fisheries management.
- Limit dredging and mining impacts on reefs in this ecoregion.

5 - Western Sumatra - Critically Endangered (CR)

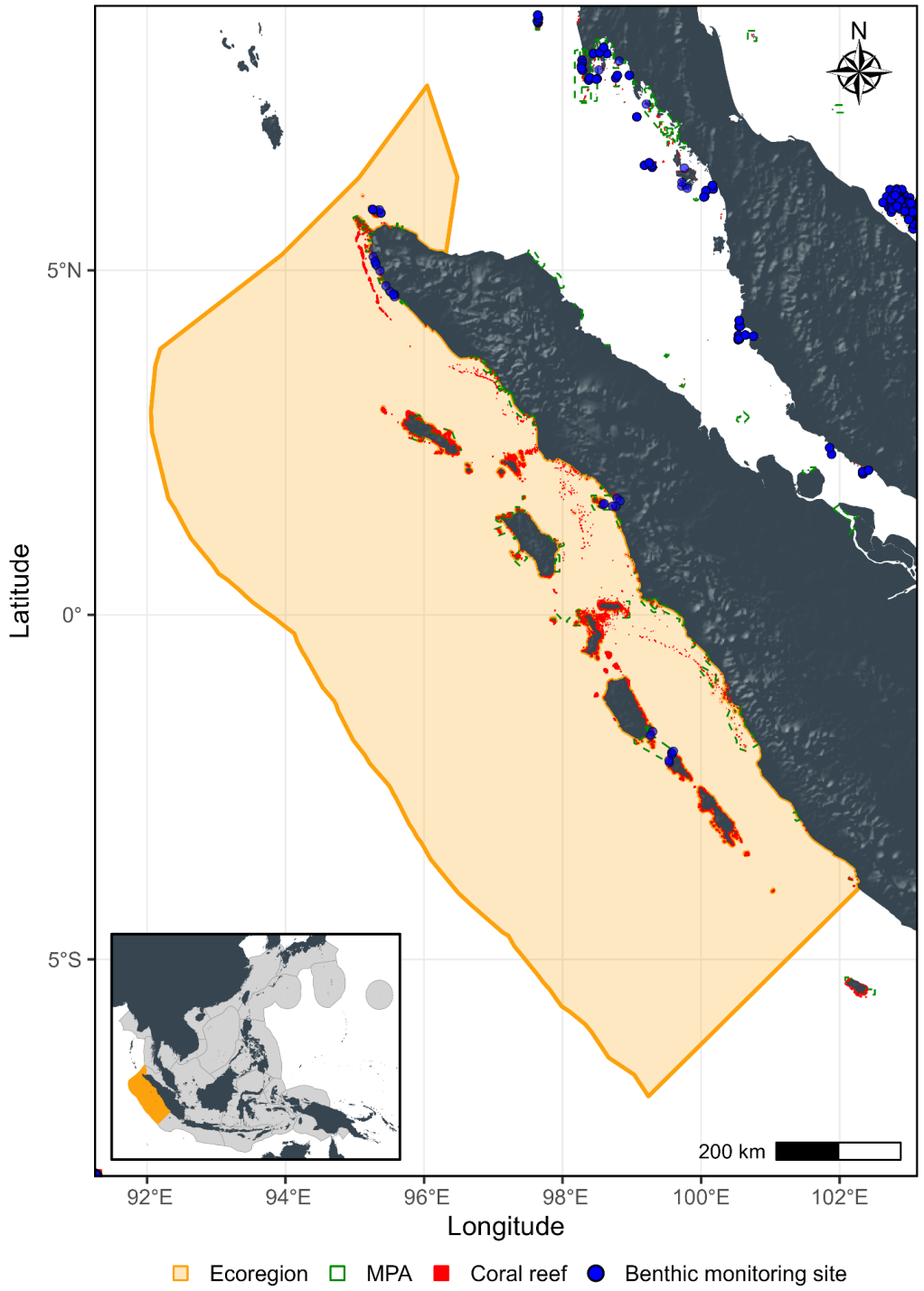


Figure 21 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Western Sumatra ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Western Sumatra coral reef ecoregion extends between 6.98°S and 7.67°N, 92.06°E and 102.31°E, and contains approximately 1,507.6 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). It extends along the western coast of Sumatra from its northernmost point and includes several offshore islands.

Ecosystem description

This ecoregion harbours approximately 578 scleractinian (hard) coral species (Veron et al., 2015), and is directly exposed to the Indian Ocean and the Indian Ocean Dipole (IOD), which is a major abiotic driver of upwelling activity, and therefore nutrient availability and water temperature. Reefs in this region formerly experienced an IOD-driven die-off event in 1997, after which some reefs were noted to have recovered but changed in composition, specifically the conspicuous absence of specific *Acropora* species (Quinn, 2015). The northernmost reefs in this ecoregion (around Aceh) are differentiated from others in the region by their exposure to the Andaman Sea, Malacca Strait, and Indian Ocean, and coral communities appear to be dominated by *Pocillopora* species (Baird et al., 2012). Reefs along offshore islands have a higher abundance of wave-tolerant *Pavona, Psammocora,* and *Porites*, while locations along the more sheltered mainland coastline have higher overall generic richness, and higher abundance of branching *Acropora, Pocillopora,* and *Montipora*. (Siringoringo et al., 2015).

Some known threats to reefs in the region are unsustainable and intensive fishing practices, anthropogenic increases in sediment, and pollution from terrestrial sources (Siringoringo et al., 2015), with the 1997 die-off event linked specifically to agriculture-driven burning and use of iron fertilizers (Abram et al., 2003).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
12.2%	231,578.42	415	Hard coral cover (%)	46.8 *	35.1
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	1.93 *	4.61
			Grouper density (ind. 100 m^{-2})	2.3 *	0.83

* Baselines for hard coral, parrotfish and grouper borrowed from the Andaman Sea Coral Coast ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Western Sumatra** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	LC	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)
	VU	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, driven by C2. Based on historical declines and present conditions alone, the status is VU, which is mainly driven by D.
- Criterion A is LC (12.2%). Criterion B is LC.
- C1 is LC, even with DHW thresholds set 1 DHW below those supported by bleaching records. This does not imply however that reefs escaped warming, as the 2010 heatwave caused high coral mortality at Pulau Weh (Guest et al., 2012).
- Criterion D is VU, driven by declines in groupers (2.30 to 0.83 ind. 100 m^{-2}, EN). Hard coral cover (46.8% to 35.1%) is LC and parrotfish is NT. All baselines were borrowed from the Andaman Sea Coral Coast.

Recommendations:

- Establish local reference sites to derive ecoregion-specific baselines.
- Reduce pollution, sedimentation and agricultural runoff.
- Monitor heat and cold stress events linked to the Indian Ocean Dipole.

6 - Gulf of Tonkin - Critically Endangered (CR)

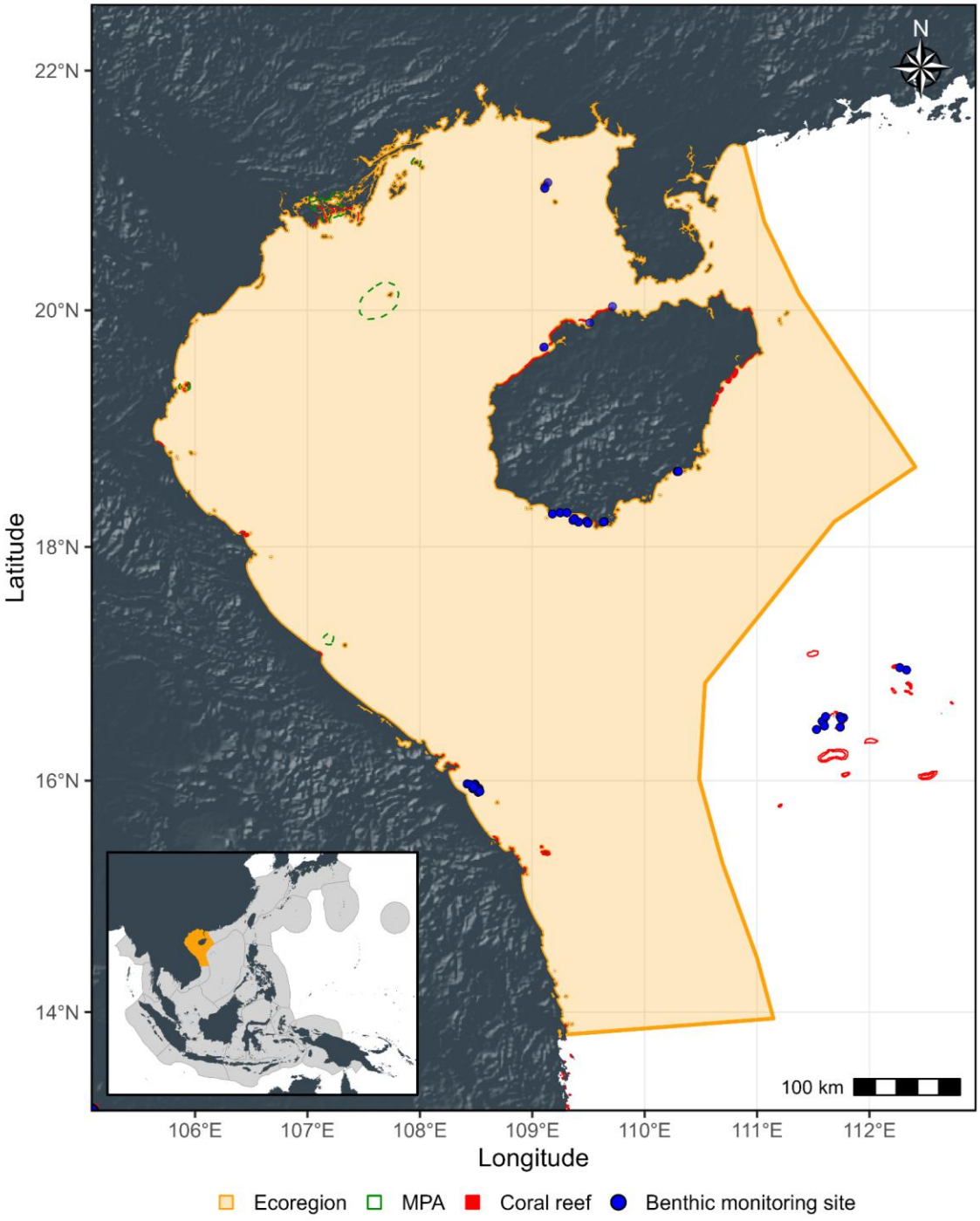


Figure 22 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Gulf of Tonkin ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Gulf of Tonkin coral reef ecoregion extends between 13.81°N and 21.92°N, 105.62°E and 112.41°E, and contains approximately 248.6 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). In this region, there is little development of fringing reefs other than around the Cu Lao Cham islands in the extreme south of the ecoregion, and most coral grows on unconsolidated rubble or submerged karst, particularly in and around Ha Long Bay and Cat Ba Island in the north (Veron et al., 2015).

Ecosystem description

This region harbours approximately 361 scleractinian (hard) coral species (Veron et al., 2015). It is dominated by non-reef coral communities developed on rubble and karst substrates rather than on accreted reef framework (Veron et al., 2015).

The Gulf of Tonkin is largely composed of shallow isobaths with a depth range of 50–60 m. Consequently, the observed annual temperature range is large (June–August: 29–32 °C; October–March: 16 °C). High degree of river discharge in the western and northwestern parts of the Gulf introduces large quantities of terrigenous sediment and decreases salinity. Upwelling off the coast of Hainan Island occurs during June–August (summer). Regional reefs are dominated by high proportions of massive *Porites* and *Favites*, whose stress tolerance is more well adapted to relatively extreme conditions and high turbidity (Latypov, 2003).

Reefs in the Gulf of Tonkin face a range of local anthropogenic impacts: fishing, aquaculture, port activities, land reclamation, dredging and dumping, mining, and tourism-related impacts. In addition to climate warming and its downstream impacts, reefs also face naturally occurring threats, including extreme water temperatures, typhoons, wave action, high turbidity, salinisation, and local freshening (Tran et al., 2026).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
12%	266,920.77	61	Hard coral cover (%)	34.3	27.6
			Algae : coral ratio	0.14	0.17
			Parrotfish density (ind. 100 m^{-2})	0.21	0.21
			Grouper density (ind. 100 m^{-2})	1.71	1.71

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the **Gulf of Tonkin** was assessed as **Critically Endangered (CR).** Summary of the assessment:

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

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, which is mainly driven by C2. Based on historical declines and present conditions alone, the status is EN (driven by C1).
- Criterion A is LC (12.0%). Criterion B is LC.
- C1 is EN.
- Criterion D is VU. Hard coral cover declined from 34.3% to 27.6% (NT). Parrotfish are VU and groupers LC.

Recommendations:

- Limit land reclamation, dredging and aquaculture near reefs.
- Expand reef fish monitoring beyond the reference sites.

7 - Southern China - Critically Endangered (CR)

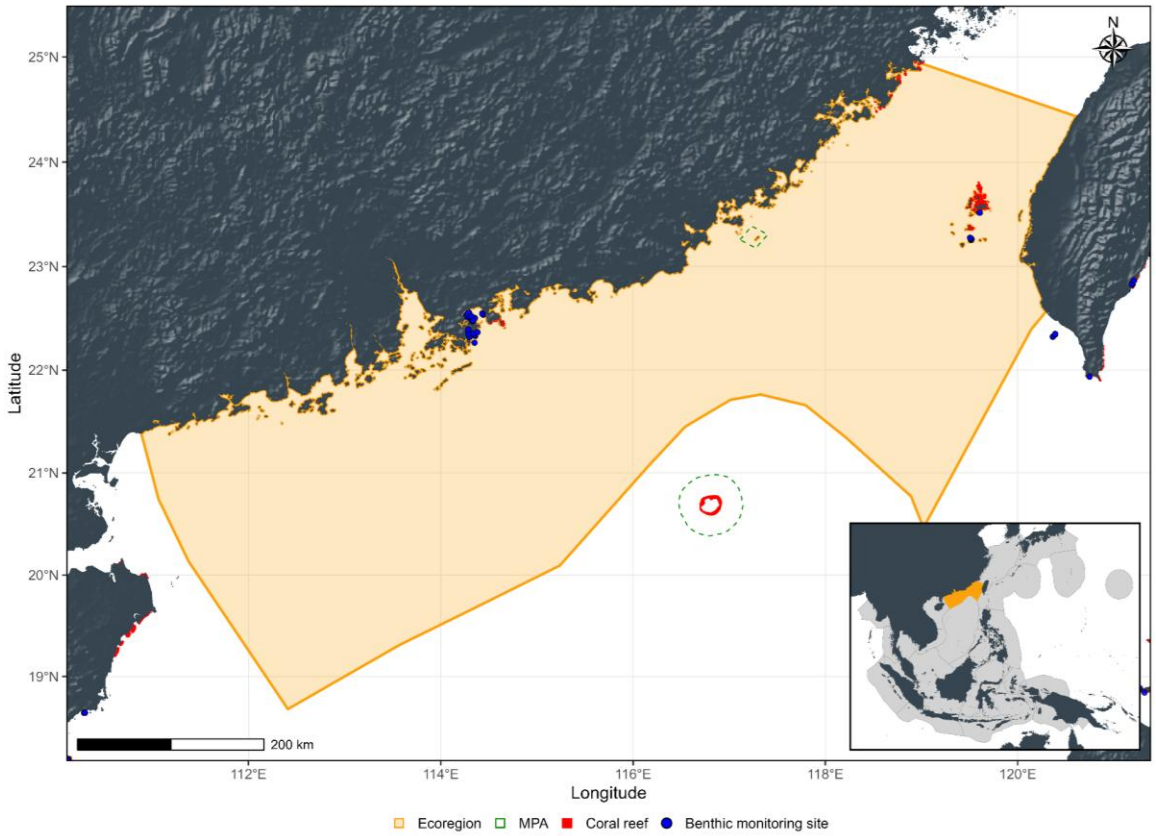


Figure 23 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Southern China ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Southern China coral reef ecoregion extends between 18.68°N and 24.99°N, 110.88°E and 120.61°E, and contains approximately 178.2 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). In this region, fringing reefs occur sporadically on the north, north-east and south sides of Hainan Island, separated by sandy beaches, rocky headlands and estuaries. On the southern Chinese mainland coast, a few small patches of unconsolidated reef occur on small offshore islets (Veron et al., 2015). Following feedback from GCRMN East Asia national coordinators, 8 records from the Western Fangji Island in China were excluded as non-reefal environments where corals grow on rocky substrata rather than on accreting coral reefs.

Ecosystem description

The Southern China ecoregion harbours approximately 436 scleractinian (hard) coral species and is dominated by sporadic fringing reefs on Hainan Island, with limited reef occurrence on the adjacent mainland coast (Veron et al., 2015). Reef waters around Hainan range from clear to turbid and are very turbid in heavily populated embayments, while mainland reef

waters are partly turbid (Veron et al., 2015). Many reefs have been badly impacted by typhoons, bleaching, COTS (*Acanthaster* spp.) outbreaks, overfishing (including highly destructive practices), coastal development, aquaculture and coastal tourism have expanded markedly in recent decades around Sanya in southern Hainan (Veron et al., 2015). The combination of sporadic fringing-reef development, contrasting reef-water clarity between offshore and embayment settings, and intense compounding pressures creates ecological dynamics unique to the Southern China ecoregion.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
2.6%	73,761.19	26	Hard coral cover (%)	57.6	41.1
			Algae : coral ratio	0.02	0.05
			Parrotfish density (ind. 100 m^{-2})	5.76 *	0.54
			Grouper density (ind. 100 m^{-2})	1.38 *	0.15

* Baselines for parrotfish and grouper borrowed from the Southern Vietnam ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Southern China** was assessed as **Critically Endangered (CR).** Summary of the assessment:

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

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

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, driven by C1 and C2. Based on historical declines and present conditions alone, the status is also CR.
- Criterion A is LC (2.6%). Criterion B is VU (AOO 26), reflecting low overall reef area that is mainly concentrated around Hainan.
- C1 is CR.
- Criterion D is EN. Hard coral cover declined from 57.6% to 41.1% (NT). Parrotfish (5.76 to 0.54 ind. 100 m^{-2}) and groupers (1.38 to 0.15 ind. 100 m^{-2}) are both CR, relative to baselines borrowed from Southern Vietnam.

Recommendations:

- Lower fishing pressure through expanded no-take zones around Hainan
- Control coastal development, aquaculture and pollution.
- Monitor and manage COTS outbreaks.

8 - South China Sea Oceanic Islands - Critically Endangered (CR)

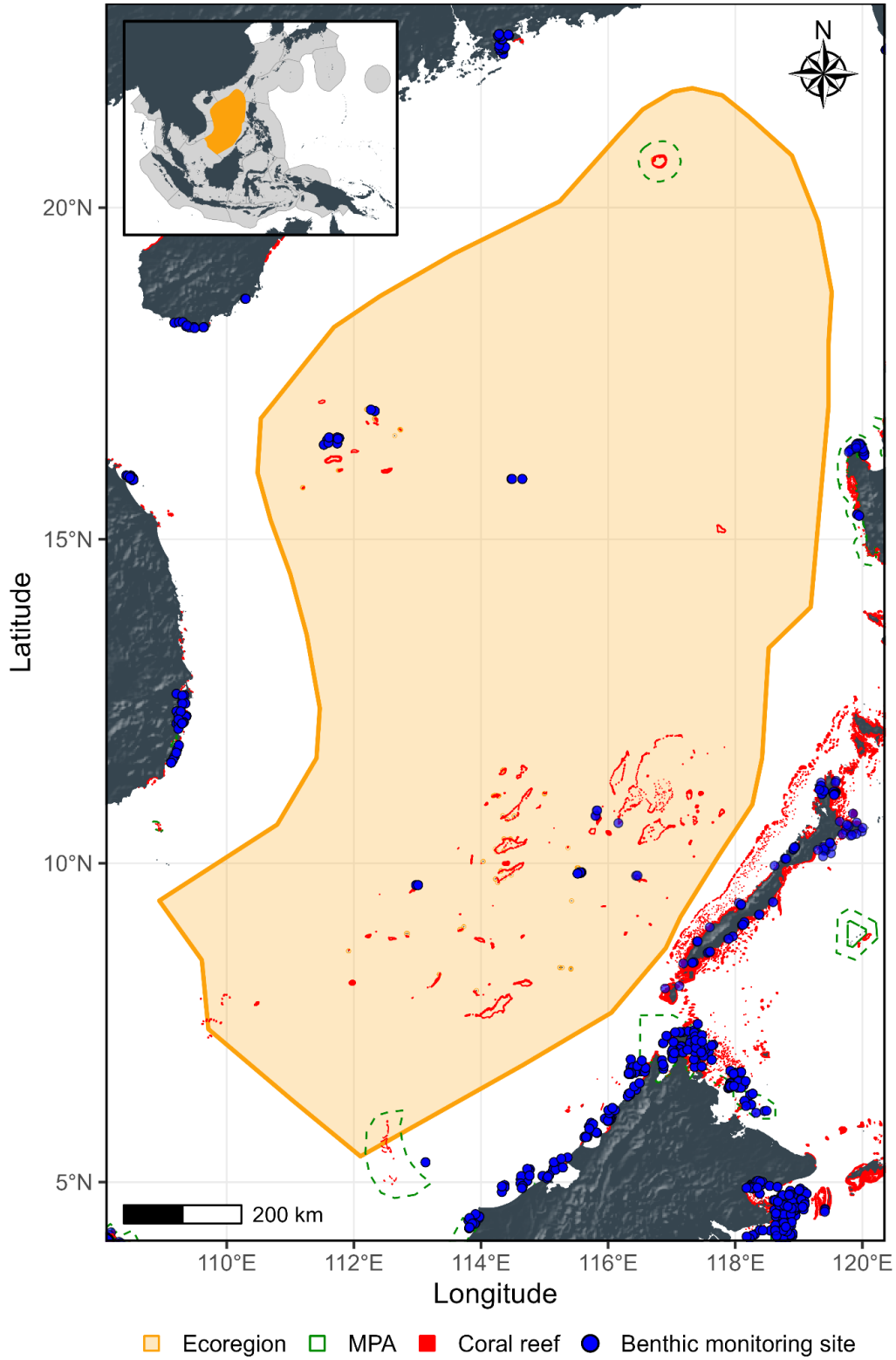


Figure 24 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the South China Sea Oceanic Islands ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The South China Sea Oceanic Islands coral reef ecoregion extends between 5.41°N and 21.76°N, 108.94°E and 119.52°E, and contains approximately 3,289.0 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). On the eastern side of this ecoregion an extensive line of platform reefs and atolls is aligned in rows parallel to Palawan, with the Spratly Islands forming a further extensive complex of reefs and islands in the west, the Paracel Islands forming a large archipelago in the north-west, and widely dispersed islands and seamounts in the southern part (Veron et al., 2015).

Ecosystem description

The South China Sea Oceanic Islands ecoregion harbours approximately 563 scleractinian (hard) coral species, and comprises extensive offshore reef systems aligned along major archipelagic and seamount complexes. Reef waters are mostly clear except where adjacent to coastlines (Veron et al., 2015). The ecoregion is heavily exploited by fisheries, with overfishing and destructive fishing impacting reef systems (Veron et al., 2015). The combination of extensive platform reefs, atolls and seamount-associated reef systems across multiple offshore archipelagos, generally clear oceanic waters, and intense fisheries exploitation creates ecological dynamics unique to the South China Sea Oceanic Islands ecoregion.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
44.4%	1,031,657.08	345	Hard coral cover (%)	-	-
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	-	-
			Grouper density (ind. 100 m^{-2})	-	-

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **South China Sea Oceanic Islands** was assessed as **Critically Endangered (CR).** Summary of the assessment:

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

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, mainly driven by C2. Based on historical declines and present conditions alone, the status is VU (driven by criterion A).
- Criterion A is VU, with 44.4% of sites below 10% hard coral cover.
- Criterion B is LC. C1 is NT.
- Criterion D is DD, as neither hard coral baselines nor fish data were available.

Recommendations:

- Establish standardised long-term benthic and fish monitoring programs across the ecoregion.
- Strengthen regional cooperation to reduce destructive fishing and reef loss from land reclamation.

9 - Gulf of Thailand - Critically Endangered (CR)

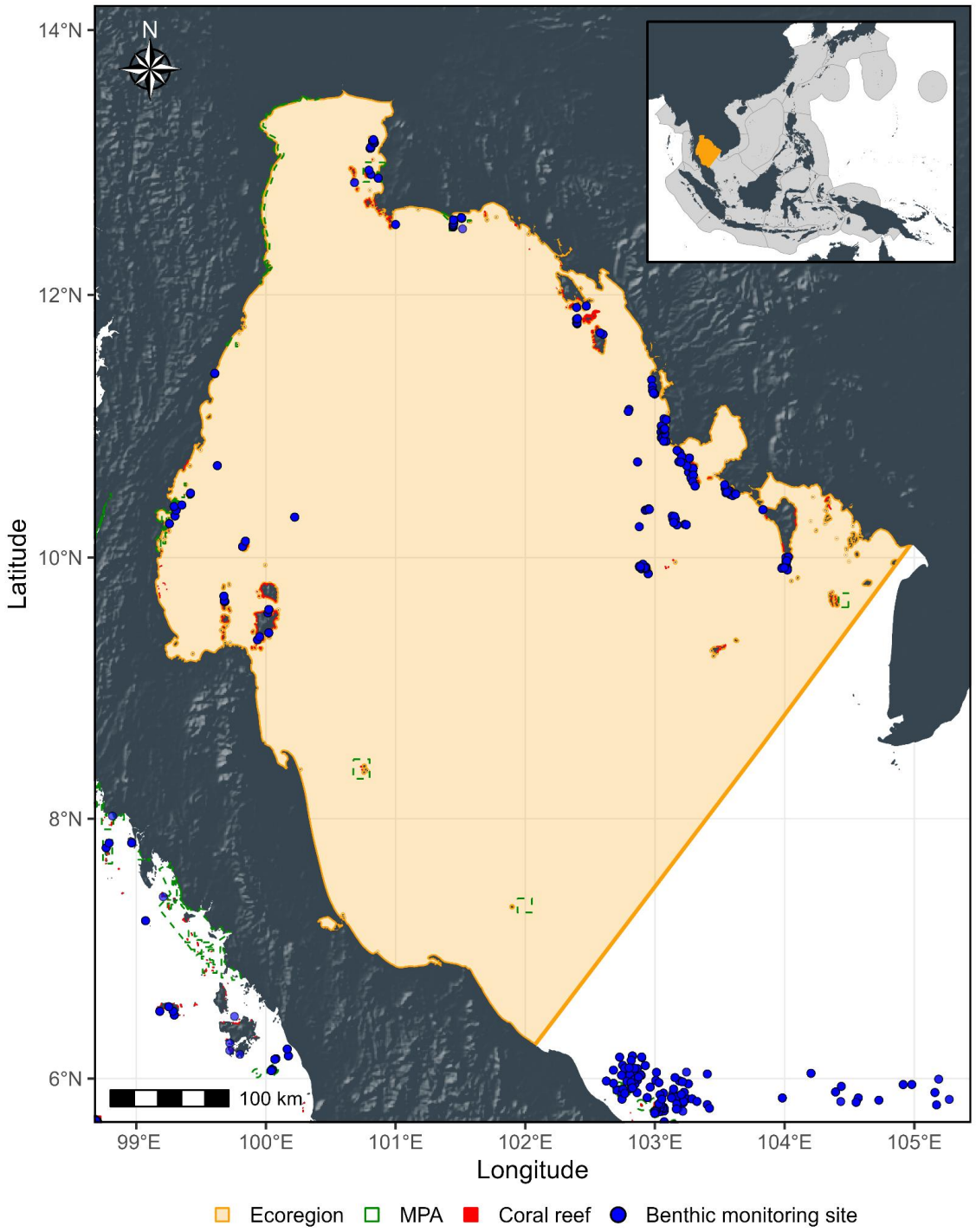


Figure 25 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Gulf of Thailand ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Gulf of Thailand coral reef ecoregion extends between 6.25°N and 13.61°N, 99.14°E and 104.97°E, and contains approximately 144.6 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). It is a shallow semi-enclosed extension of the South China Sea bounded by the southern coastlines of Thailand, Cambodia and Vietnam, totallying about 1600 km in length.

Ecosystem description

This region harbours approximately 401 scleractinian (hard) coral species (Veron et al., 2015). It is subject to monsoonal variations (southwest monsoon from May to September and northeast monsoon from October to February) and to sediment input from major river outflows along the gulf coast, with nutrient influx into the shallow reefs driven by upwelling (Sojisuporn et al., 2010).

Coral diversity is sustained by stress-tolerant species better adapted to high sedimentation rates, nutrient influx, and large salinity variations; reefs are typically dominated primarily by massive *Porites*, and subsequently by *Pavona*, *Diploastrea* and *Acropora* spp. (Yeemin et al., 2009; Monchanin et al., 2025), and offshore reef sites generally have higher coral cover and diversity, with higher abundance of *Acropora* species (Monchanin et al., 2025). Grazing by herbivorous fish and invertebrates has also been indicated to contribute to reef health (Stuhldreier et al., 2015).

Regional reefs face threats in overfishing, destructive fishing, eutrophication, sedimentation, coastal development, unsustainable tourism, and thermal stress (Tun et al., 2008; Yeemin et al., 2009), and are noted to have been impacted by previous global coral bleaching events (Yeemin et al., 2009; Phongsuwan et al., 2013).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
2.1%	186,300.79	89	Hard coral cover (%)	54.5	45.5
			Algae : coral ratio	0.07	0.03
			Parrotfish density (ind. 100 m^{-2})	3.25	2.63
			Grouper density (ind. 100 m^{-2})	1.6	1.38

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the **Gulf of Thailand** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	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		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, which is mainly driven by C2. Based on historical declines and present conditions alone, the status is VU (driven by C1 and D).
- Criterion A is LC (2.1%). Criterion B is LC.
- C1 is VU.
- Criterion D is VU, driven by declines in parrotfish (3.25 to 2.63 ind. 100 m^{-2}) and groupers (1.60 to 1.38 ind. 100 m^{-2}), which were both evaluated as VU. Hard coral cover (54.5% to 45.5%) and the algae-coral ratio are LC.

Recommendations:

- Strengthen fisheries management and enforcement in nearshore waters.
- Reduce eutrophication and coastal development to minimize impacts on reefs.
- Improve the management of tourism pressure at heavily visited reefs.

10 - Southern Vietnam - Critically Endangered (CR)

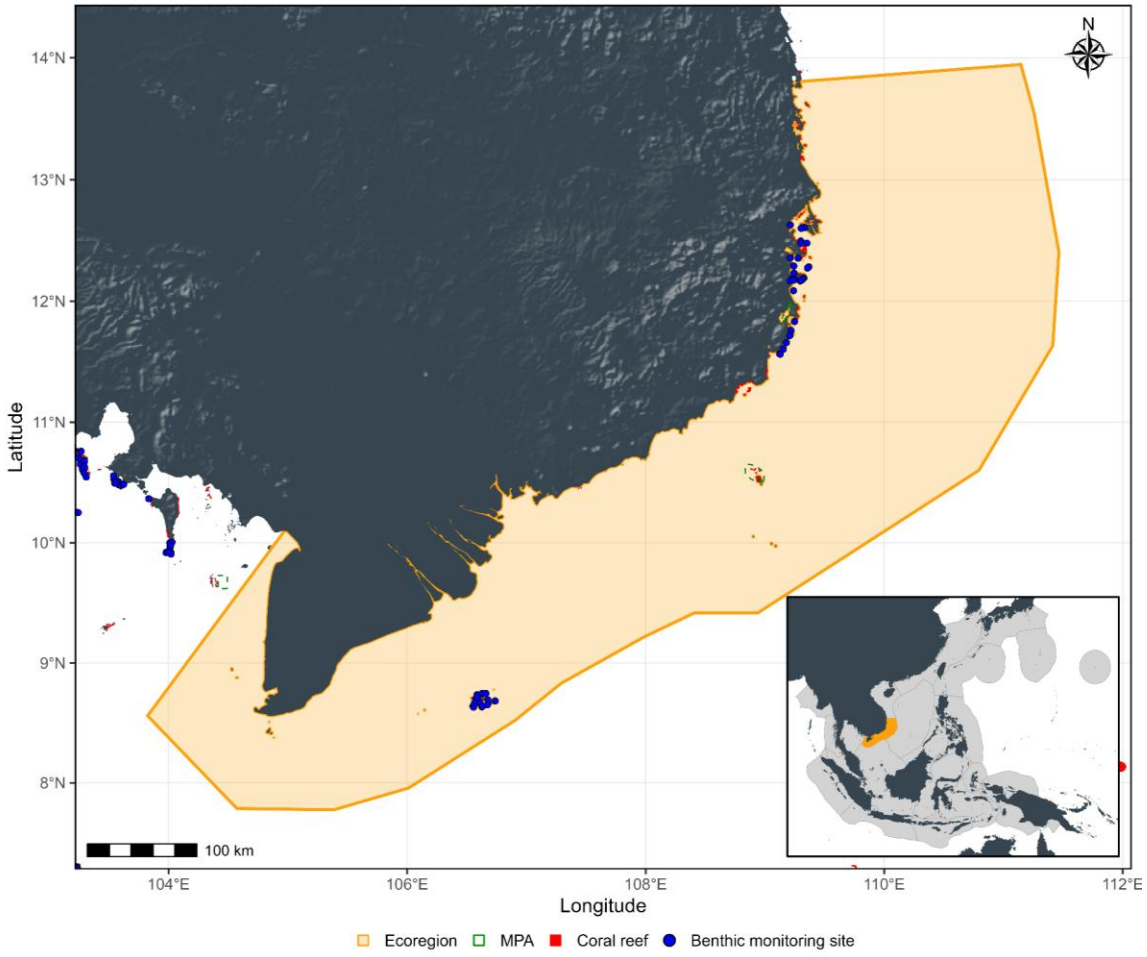


Figure 26 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Southern Vietnam ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Southern Vietnam coral reef ecoregion extends between 7.77°N and 13.95°N, 103.82°E and 111.47°E, and contains approximately 103.9 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). It encompasses an area containing mainland southern to central Vietnam, and a buffer of marine area including several groups of islands, notably around Con Dao and Nha Trang (Veron et al., 2015).

Ecosystem description

Southern Vietnam harbours approximately 364 scleractinian (hard) coral species (Veron et al., 2015). Fringing reefs are found along the coast of the mainland in areas not affected by river discharges, as well as around all islands (Veron et al., 2015). The reefs around south to central Vietnam are subject to monsoon-driven upwelling during May–August, which lowers

water temperatures and ameliorates thermal stress and the severity of bleaching events (Tkachenko et al., 2025).

Numerous localised anthropogenic threats are present, including overfishing, cage-based aquaculture, dredging and dumping activities, and coastal development (Tkachenko et al., 2016). These impacts have been reported alongside an increase in COTS outbreaks and density as a secondary threat (Tkachenko et al., 2016; Tkachenko et al., 2023). Reef health indicators like coral cover and macroalgae abundance indicate higher quality reefs on offshore islands and other sites farther from the mainland (Tkachenko et al., 2016, Thai et al., 2026). Large adult colonies of *Acropora* are still present in remote areas (Tkachenko et al., 2016). Climate warming represents another threat, and unprecedented bleaching events in southern Vietnam in 2024 indicate that recent thermal stressors are beginning to surpass historical thresholds (Tkachenko et al., 2025).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
50.9%	65528.67	45	Hard coral cover (%)	40.7	14.4
			Algae : coral ratio	0.15	0.47
			Parrotfish density (ind. 100 m^{-2})	5.76	8
			Grouper density (ind. 100 m^{-2})	1.38	0.7

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Southern Vietnam** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	EN	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	VU	NE
	C1	C2	C3

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

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

Key findings and recommendations

Key findings:

- Overall status CR across all criteria, which is mainly driven by C2. Based on historical declines and present conditions alone, the status is EN (driven by criteria A and D).
- This is the only East Asian ecoregion which is threatened under all four of Criteria evaluated (A, B, C1 and D).
- Criterion A is EN, with 50.9% of sites below 10% hard coral cover, the highest proportion in the region. Criterion B is VU (AOO 45).
- C1 is VU, and unprecedented bleaching was recorded in 2024 (Tkachenko et al., 2025).
- Criterion D is EN. Hard coral cover declined from 40.7% to 14.4% (EN) and the algae-coral ratio tripled (0.15 to 0.47, VU). Groupers declined (1.38 to 0.70 ind. 100 m^{-2}, EN), while parrotfish did not (NT).

Recommendations:

- Prioritize the protection of the remaining high-cover offshore reefs such as in Con Dao.
- Control COTS outbreaks, dredging and aquaculture.

11 - Sunda Shelf/Java Sea - Critically Endangered (CR)

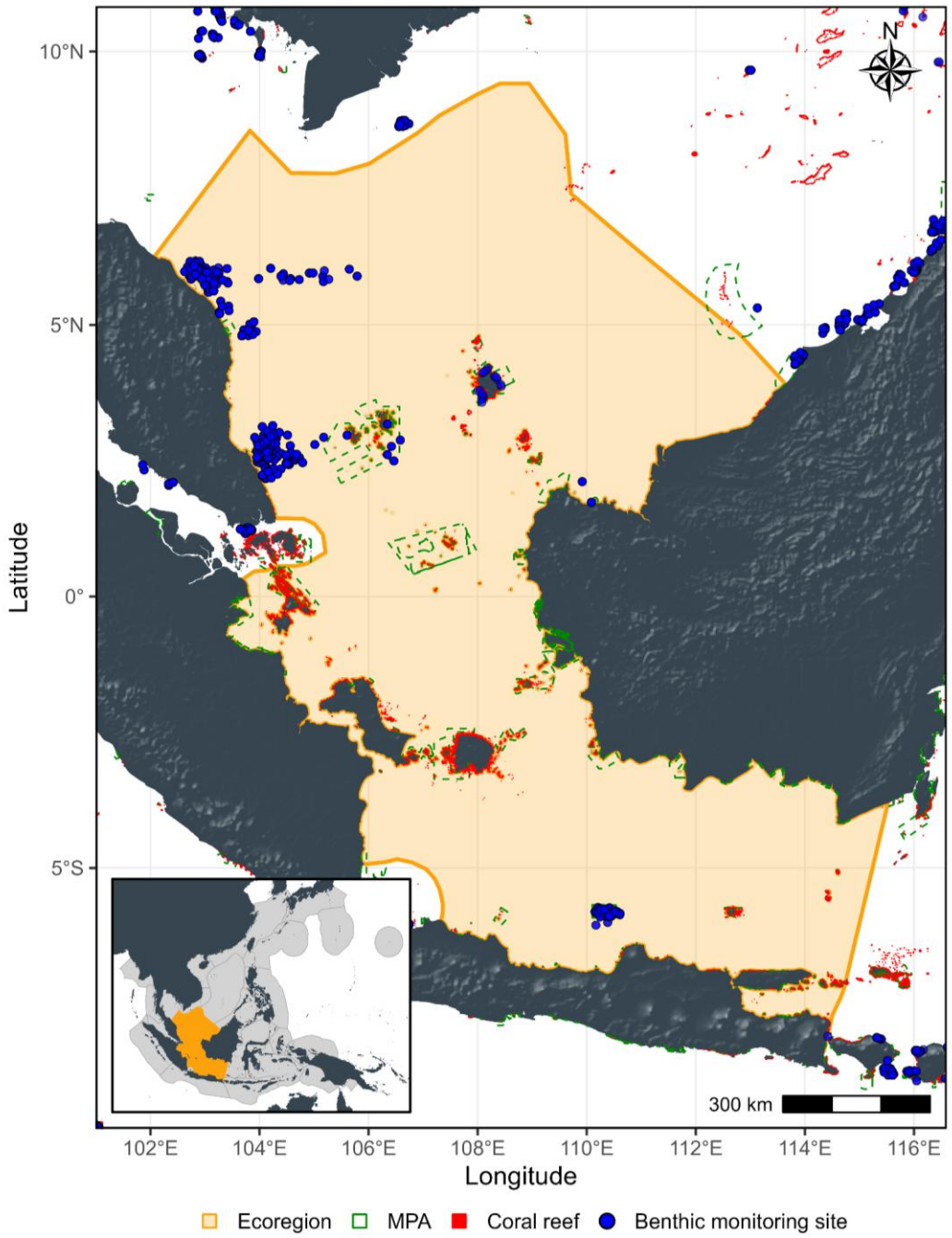


Figure 27 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Sunda Shelf/Java Sea ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Sunda Shelf/Java Sea coral reef ecoregion extends between 8.36°S and 9.42°N, 102.07°E and 115.52°E, and contains approximately 2,147.7 km^2 of coral reef (based on the UNEP-

WCMC coral reef extent layer). Reefs are bounded by the coastlines of eastern Peninsula Malaya, northeastern Sumatra, northern Java, and western Borneo.

Ecosystem description

This region harbours approximately 579 scleractinian (hard) coral species (Veron et al., 2015), and is characterized by generally clear waters, with stable temperature and salinity, with some seasonal variations influenced by the monsoons (southwest monsoon from April to August; northeast monsoon from November to March) especially along the east coast of Peninsula Malaysia (Mohd Akhir et al., 2014).

Reefs are coral-dominated with high coral species richness (Huang et al., 2015). While coral communities are typically dominated by foliose and massive coral species (Kennedy et al., 2020), they are diverse and may be dominated by a variety of lifeform categories, including branching forms of *Montipora* and *Acropora* (Edinger et al., 2000; Toda et al., 2007). Algae are typically the most dominant benthic taxa, predominantly turf algae or biofilm growing on rocky substrates, with low (<1%) macroalgal cover (Kennedy et al., 2020).

Diversity of reef fishes and feeding strategies is high, driven by the high structural complexity of reefs (Edinger et al., 2000; Afiq-Firdaus et al., 2021). The presence of top predators like sharks suggests that trophic structures are relatively intact (Afiq-Firdaus et al., 2021).

Reefs in this region are generally threatened by fishing, 'ghost nets', aquaculture and tourism; the latter is especially prevalent along the east coast of Peninsular Malaysia (Shahbudin et al., 2017). Coastal development as a threat is localised to parts of eastern Peninsular Malaysia; for example, the port of Kuantan and southeast Johor (Kimura et al., 2022). Reefs were also negatively impacted by the global bleaching event in 2016, leading to declines in coral cover (examples of impacted areas include eastern Peninsular Malaysia (Kimura et al., 2022), and Karimunjawa (Kennedy et al., 2020)).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
2.5%	1,659,635.22	503	Hard coral cover (%)	68.1	51.9
			Algae : coral ratio	0.05	0.09
			Parrotfish density (ind. 100 m^{-2})	3.21	6.85
			Grouper density (ind. 100 m^{-2})	0.63	0.85

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Sunda Shelf / Java Sea** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	LC	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1970)	Future or any 50y period	Historical (1750)
	NT	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		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, which is mainly driven by C2. Based on historical declines and present conditions alone, the status is NT (driven by criteria C1 and D). It is one of only three ecoregions not threatened based on these criteria.
- Criterion A is LC (2.5%). Criterion B is LC.
- C1 is NT.
- Criterion D is NT. Hard coral cover remains high (68.1% to 51.9%). Mean parrotfish and grouper densities exceed baselines, but declines at some sites resulted in NT.

Recommendations:

- Prioritize the protection of these comparatively intact reefs as potential refuges.
- Remove ghost nets and marine debris, and regulate aquaculture and tourism.

12 - Malacca Strait - Critically Endangered (CR)

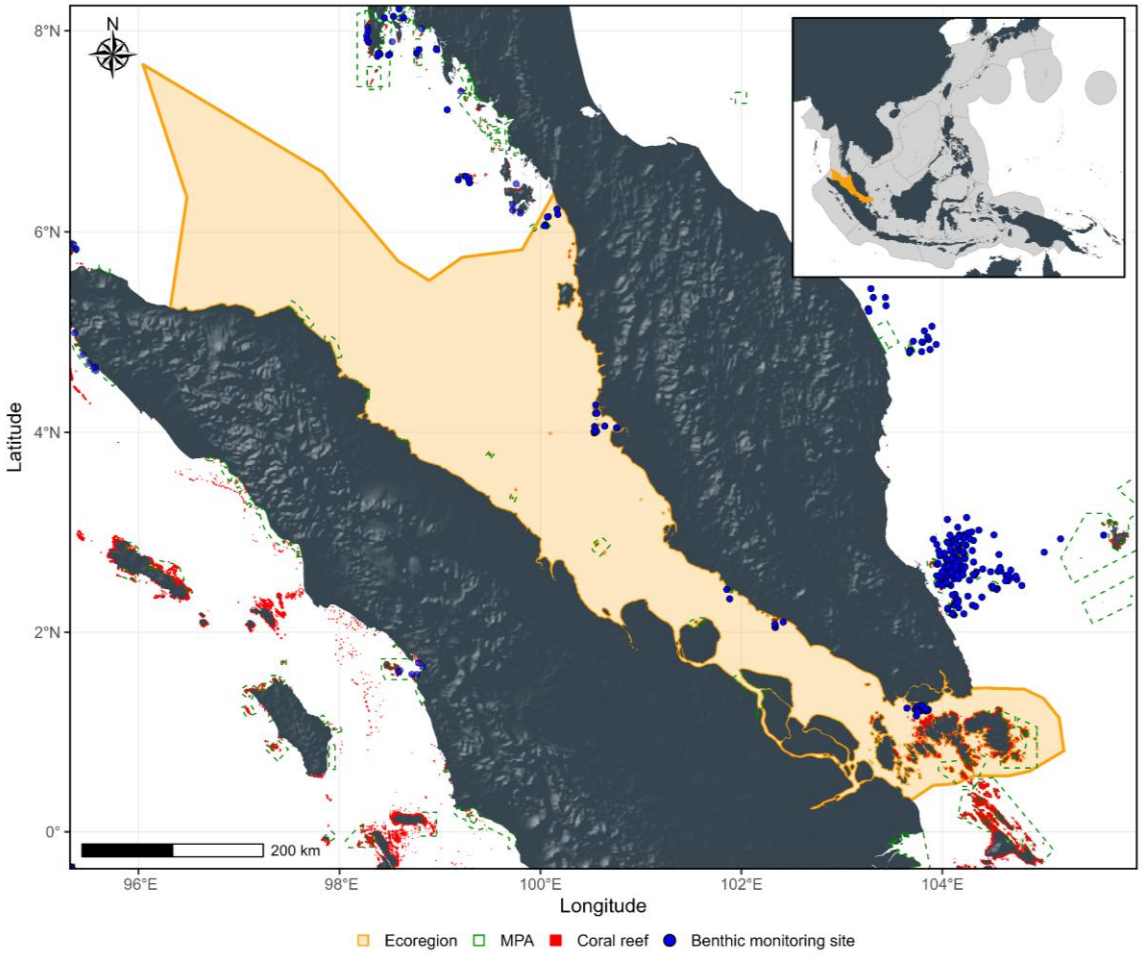


Figure 28 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Malacca Strait ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Malacca Strait coral reef ecoregion extends between 0.22°N and 7.67°N, 96.04°E and 105.21°E, and contains approximately 164.9 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). The Malacca Strait coral reef ecoregion occupies the narrow strait between the west coast of Peninsular Malaysia and the north-east coast of Sumatra (Spalding et al., 2007). Reefs comprise both nearshore marginal, turbid habitats such as those at Port Dickson and around Singapore, and more structurally developed reef systems adjacent to offshore islands, with large reef areas surrounding the Riau Archipelago between Singapore and Sumatra.

Ecosystem description

Malacca Strait harbours approximately 575 scleractinian (hard) coral species (Veron et al., 2015). Coral reefs in this ecoregion face severe turbidity and intense human pressures, yet they continue to survive right along one of the world's busiest shipping channels (Chou, 2006). Extremely high turbidity caused by Sumatran rivers and tidal resuspension, strong tidal currents and chronically high sedimentation rates restrict reef development almost entirely to depths shallower than about 10 m, with low light penetration dominating the benthic environment. Despite these conditions, the ecoregion supports relatively diverse reefs dominated by turbid-water specialists and stress-tolerant corals, including massive *Porites* and members of the Merulinidae (Wong et al., 2018). Coral diversity is sustained by stress-tolerant and generalist species capable of withstanding high sedimentation rates (Bollati et al., 2022) and low-light conditions (Toniolo et al., 2026), but reef structural complexity is typically low relative to benthic diversity (Bauman et al., 2022). Herbivore taxonomic diversity is low, yet macroalgal removal rates are sustained by a small number of dominant fish species (Bauman et al., 2017).

The main threats include chronic sedimentation from rivers and coastal construction, intense shipping traffic, coastal development and land reclamation, pollution, overfishing and thermal stress (Chou et al., 2019; Ng et al., 2020). The combination of high turbidity, chronic sedimentation, intense shipping and coastal urbanisation, together with a reef community dominated by stress-tolerant coral taxa, creates ecological dynamics unique to the Malacca Strait ecoregion.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
9.5%	124,806.63	81	Hard coral cover (%)	46.4	32.7
			Algae : coral ratio	0.06	0.17
			Parrotfish density (ind. 100 m^{-2})	3.21 *	1.8
			Grouper density (ind. 100 m^{-2})	0.63 *	1.56

* Baselines for parrotfish and grouper borrowed from the Sunda Shelf / Java Sea ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Malacca Strait** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	LC	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1970)	Future or any 50y period	Historical (1750)
	NT	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		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, and is mainly driven by C2. Based on historical declines and present conditions alone, the status is VU (driven by D).
- Criterion A is LC (9.5%), including sites lost to land reclamation in Singapore. Criterion B is LC.
- C1 is NT.
- Criterion D is VU, driven by parrotfish (3.21 to 1.80 ind. 100 m^{-2}, EN). Hard coral cover declined from 46.4% to 32.7% (NT) and groupers are NT. Fish baselines were borrowed from the Sunda Shelf/Java Sea.

Recommendations:

- Avoid further reef loss from land reclamation and require thorough environmental impact assessments for new projects.
- Protect herbivores, as macroalgal removal depends on a few species (Bauman et al., 2017).
- Reduce sedimentation from coastal development and dredging.

13 - Southern Java - Critically Endangered (CR)

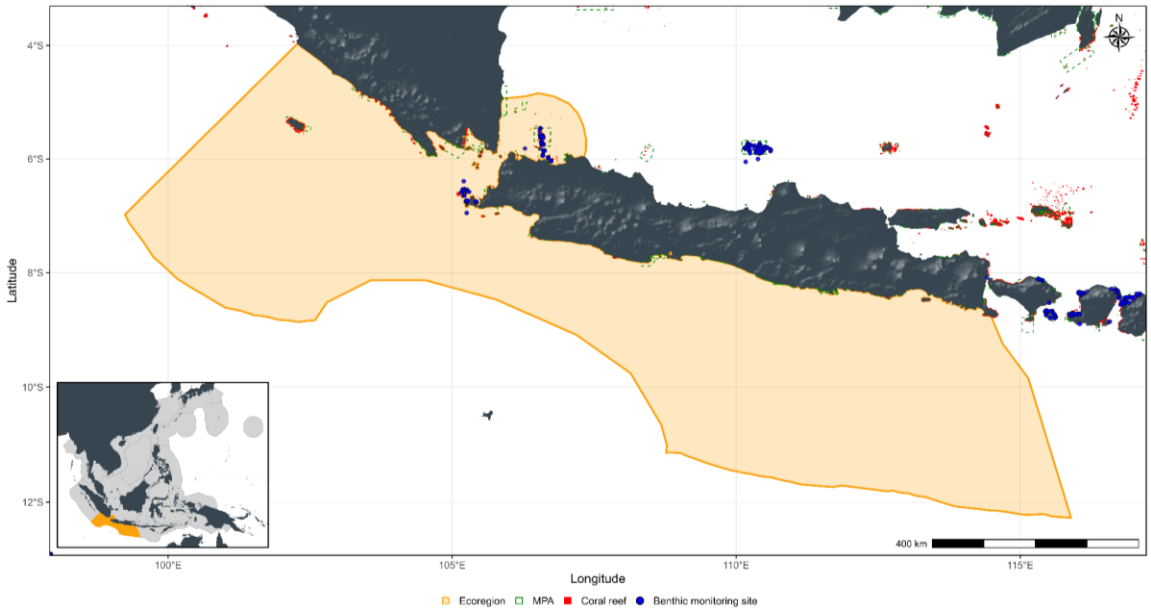


Figure 29 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Southern Java ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Southern Java coral reef ecoregion extends between 12.27°S and 3.97°S, 99.24°E and 115.90°E, and contains approximately 196.4 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). Reefs in this ecoregion are located along the southern coasts of the West Java province, along the coasts of the Banten province, and along the northern coast directly west of Jakarta. Offshore reefs are located among the Thousand Islands archipelago and Panaitan Island. (Aulia et al., 2024).

Ecosystem description

Southern Java harbours approximately 578 scleractinian (hard) coral species (Veron et al., 2015). Reefs here are exposed to both heat stress and cold stress events, driven by strong ENSO events and positive IOD events respectively (Watanabe et al., 2026), and represent perennial natural disturbances to local reefs, the former of which is further exacerbated by climate warming. Localised threats are generally focused around the urban centre of Jakarta, and the Thousand Islands archipelago to its north. Reef condition generally, but not always, improves with distance from populated areas and associated anthropogenic stressors (Cleary et al., 2006), with pollution (sedimentation, nitrate, phosphate, etc.) being a good predictor of reef quality and benthic composition (Baum et al., 2015).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
18.2%	201,560.67	125	Hard coral cover (%)	54.5 *	33.5
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	28.14 *	26.12
			Grouper density (ind. 100 m^{-2})	4.6 *	3.79

* Baselines for hard coral were borrowed from the Lesser Sunda ecoregion, while those for parrotfish and grouper were borrowed from Papua.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Southern Java** was assessed as **Critically Endangered (CR).** Summary of the assessment:

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

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, mainly driven by C2. Based on historical declines and present conditions alone, the status is EN (driven by C1).
- Criterion A is LC (18.2%). Criterion B is LC.
- C1 is EN, reflecting heat stress linked to ENSO and the Indian Ocean Dipole.
- Criterion D is VU. Hard coral cover declined from 54.5% (borrowed from Lesser Sunda) to 33.5% (VU). Groupers are VU and parrotfish LC, relative to baselines borrowed from Papua.

Recommendations:

- Reduce pollution near Jakarta, particularly in and around the Thousand Islands.
- Monitor both heat and cold stress events.
- Establish local reference sites.

14 - South Kuroshio - Critically Endangered (CR)

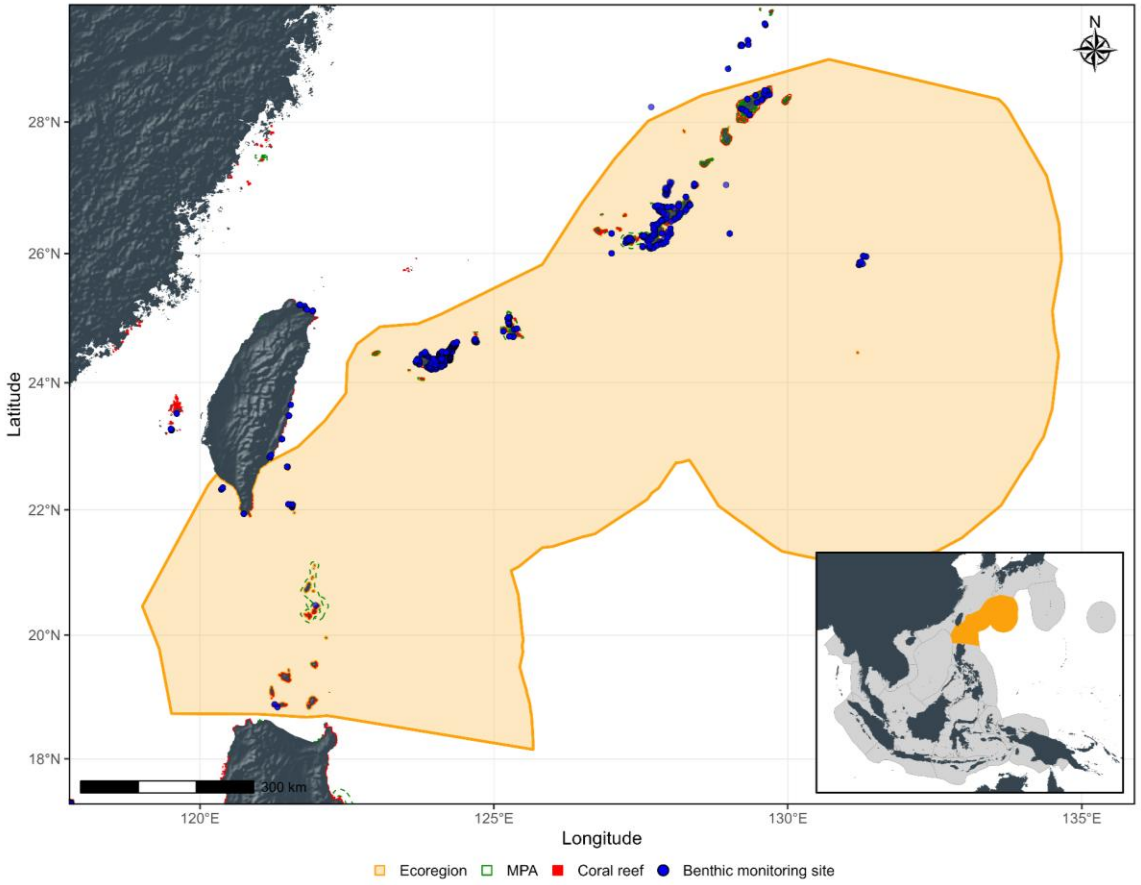


Figure 30 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the South Kuroshio ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The South Kuroshio coral reef ecoregion extends between 18.15°N and 28.94°N, 119.02°E and 134.66°E, and contains approximately 906.0 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). The area extends from the Babuyan and Batanes Islands at the tip of northern Philippines through the southern tip of Taiwan, northwards along Ryukyu Islands to the Amami Islands, and also includes the Daito Islands, located approximately 360 km east of Okinawa Island, and Okinotori Island, an atoll located around 1000 km southeast of Okinawa Island (Spalding et al., 2007).

Ecosystem description

This region harbours approximately 579 scleractinian (hard) coral species (Veron et al., 2015). The Kuroshio Current is a major abiotic driver for regional reefs. Flowing northwards along eastern Taiwan and the western side of the Ryukyu Archipelago (Kamachi et al., 2004; Reimer et al., 2019), it acts as a dispersal corridor, facilitating the transport of larval fishes, corals, and other invertebrates from the northwestern Philippines and eastern Taiwan to

higher-latitude regions (Saito & Iguchi, 2025). This process sustains high biodiversity and enables coral reef development even at higher latitudes, such as around the Amami Islands (Reimer et al., 2019).

High-diversity reef-building coral assemblages are present, with approximately 380 species estimated to occur in the Yaeyama Archipelago and 280 in southern Taiwan, and species richness declining northwards (Chen & Keshavmurthy, 2009; Nishihira, 2004). A distinct boundary between low-latitude reef-building coral communities and high-latitude, non-reef-building coral communities occurs around Taiwan (Chen & Keshavmurthy, 2009).

Reefs face threats from recurrent mass bleaching events and destructive typhoons (Yamazato, 1999; Keshavmurthy et al., 2019; Afzal et al., 2025; Kimura et al., 2026a), as well as extensive coastal development (Meng et al., 2008; Nakajima et al., 2025).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
28.9%	654,753.65	203	Hard coral cover (%)	56.5	29.7
			Algae : coral ratio	0.38	0.41
			Parrotfish density (ind. 100 m^{-2})	1.04	0.34
			Grouper density (ind. 100 m^{-2})	0.09	0.03

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **South Kuroshio** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	NT	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	LC	NE

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	NT	NE	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1970)	Future or any 50y period	Historical (1750)
	EN	CR	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		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, driven by C2. Based on historical declines and present conditions alone, the status is EN (driven by criteria C1 and D).
- Criterion A is NT (28.9%). Criterion B is LC.
- C1 is EN, consistent with recurrent bleaching events around Okinawa (Afzal et al., 2025).
- Criterion D is EN. Hard coral cover nearly halved (56.5% to 29.7%, VU) across the ecoregion, while declines in parrotfish (1.04 to 0.34 ind. 100 m^{-2}) and groupers (0.09 to 0.03 ind. 100 m^{-2}) were both evaluated as EN.

Recommendations:

- Reduce coastal development to limit local impacts and support recovery between bleaching events.
- Strengthen protection of overfished stocks of parrotfish and groupers.

15 - Ogasawara Islands - Critically Endangered (CR)

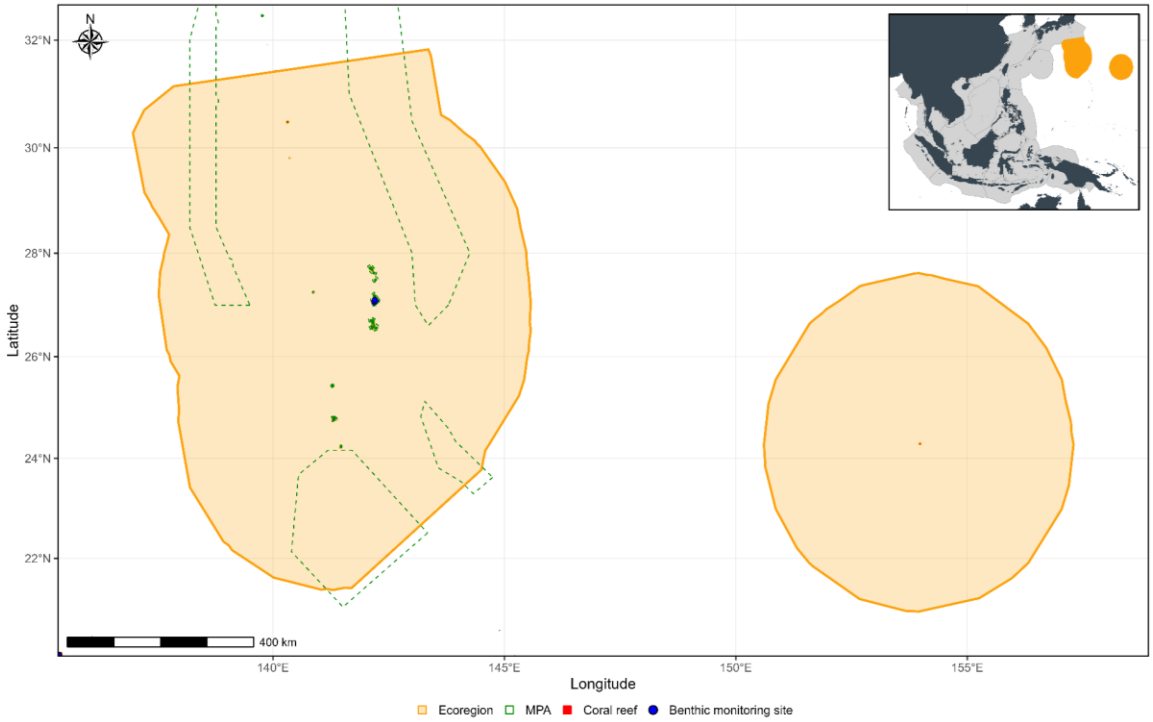


Figure 31 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Ogasawara Islands ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Ogasawara Islands coral reef ecoregion extends between 20.93°N and 31.83°N, 136.97°E and 157.30°E, and contains approximately 0.36 km^2 of coral reef based on the UNEP-WCMC coral reef extent layer. The ecoregion encompasses the Ogasawara Archipelago, the Iwo Islands, and the isolated Minamitorishima reef system. Coral reefs occur in the Ogasawara Archipelago and around Minamitorishima, whereas reef development is limited in the Iwo islands (Inaba, 2004).

Ecosystem description

Coral reefs in the Ogasawara Archipelago are generally sparsely developed, occurring mainly as discontinuous fringing and patch reefs (Inaba, 2004). Approximately 200 hermatypic coral species have been reported in the Ogasawara Archipelago (Inaba, 2004; Açıkbaş et al., 2024). Coral assemblages are characterized largely by massive and encrusting growth forms, although community composition varies among islands. In the Iwo Islands, coral communities are comparatively limited and are mainly characterized by *Porites* and *Pocillopora* (Inaba, 2004). Approximately 800 inshore fish species have been reported from the Ogasawara Islands, with the fish fauna comprising both southern and northern species (Randall et al., 1997). Unlike the Ryukyu Archipelago and mainland Japan, the Ogasawara islands lie outside the influence of the Kuroshio Current, contributing to their strong

oceanographic isolation and distinctive marine biota. Key threats include thermal stress and associated coral bleaching, together with localized terrestrial sediment runoff and coastal development, particularly harbor construction (Inaba, 2004; Ministry of the Environment of Japan, 2014).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
0%	2.33	1	Hard coral cover (%)	56.4	49.7
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	0.19	0.19
			Grouper density (ind. 100 m^{-2})	0.08	0.08

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Ogasawara Islands** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	CR	CR	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)
	LC	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, driven by criteria B, C1 and C2. Based on historical declines and present conditions alone, the status is also CR.
- Criterion A is LC (0%). Criterion B is CR due to the very small mapped reef extent (EOO 2.33 km^2, AOO 1).
- C1 is CR.
- Criterion D is LC. Hard coral cover (56.4% to 49.7%) and fish densities remained stable.

Recommendations:

- Maintain strict protection and limit red soil runoff and harbor construction.

16 - Palawan / North Borneo - Critically Endangered (CR)

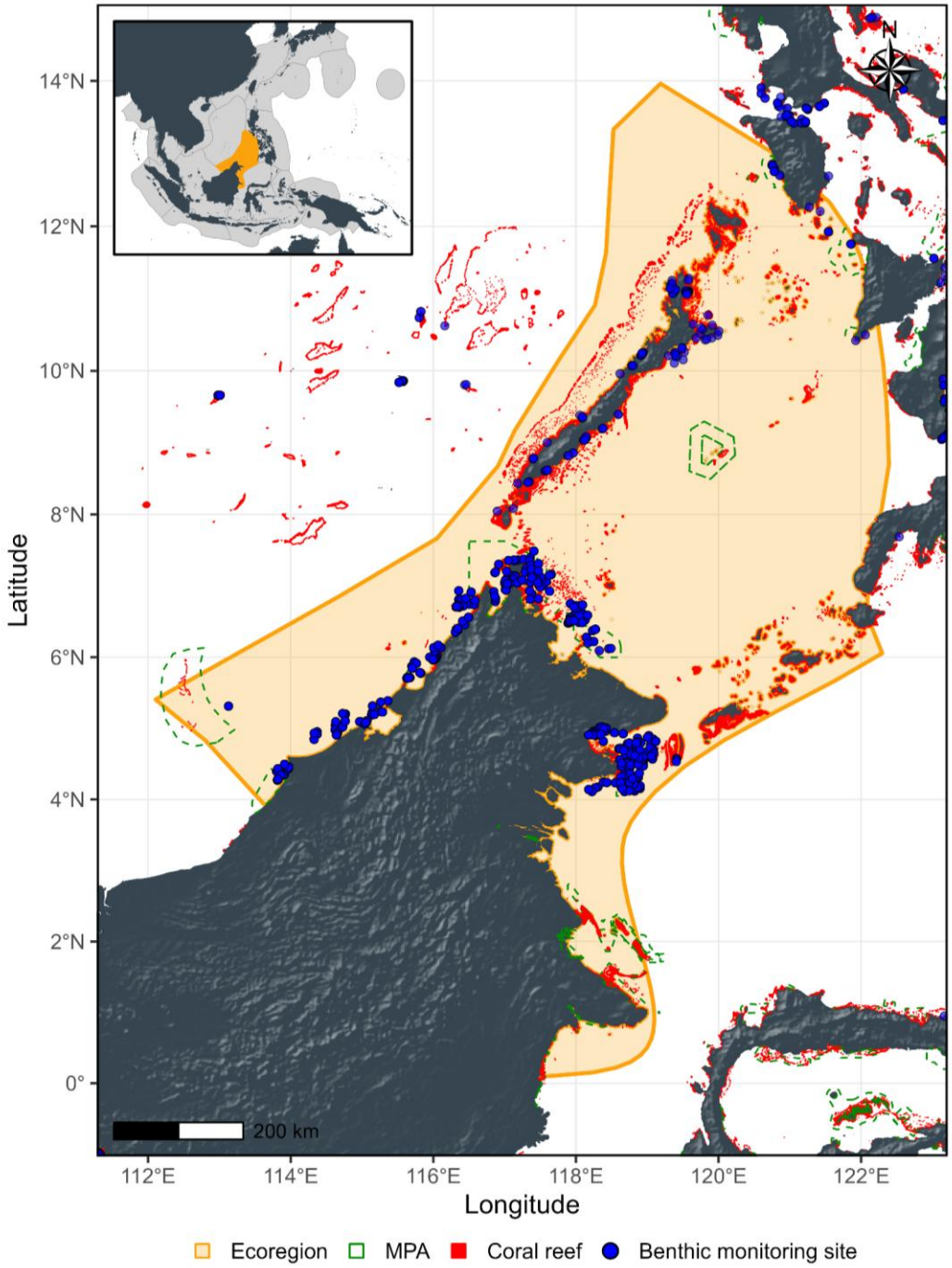


Figure 32 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Palawan / North Borneo ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Palawan/North Borneo coral reef ecoregion extends between 0.09°N and 13.96°N, 112.10°E and 122.39°E. It contains 19,684 km of coastline, and 153,206 km^2 of surface area

at less than 200 m depth (Green & Mous, 2008), corresponding to approximately 7,926.0 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). It includes parts of the West Philippine Sea surrounding Palawan Island, the Sulu Sea, and the seas around Northern Sabah, Brunei, and North Kalimantan.

Ecosystem description

This ecoregion, which harbours approximately 574 scleractinian (hard) coral species (Veron et al., 2015), is a semi-enclosed sea with a deep basin (5,000 m), with internal waves driving water ventilation across depth layers (Girton et al., 2011). It has high habitat heterogeneity ranging from various reef types, to mangroves and marine lakes (Huffard et al., 2012).

Coral species richness values here are the highest in the Coral Triangle (Devantier & Turak, 2017), and there is high diversity and endemicity of reef fish species (Balisco & Dolorosa, 2019; Fortaleza et al., 2025). This area is also a critical nesting site for green sea turtles (*Chelonia mydas*) globally (Green & Mous, 2008).

Reefs are threatened by Illegal, Unreported and Unregulated (IUU) fishing (Acevedo et al., 2026), rapid urbanization and proximity to population centers (Heery et al., 2018), plastic pollution and marine debris (Gomez et al., 2023; Liu et al., 2024), as well as extensive logging and mining leading to sedimentation (Huffard et al., 2012).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
8.6%	868,332.52	1,015	Hard coral cover (%)	52.2	30.4
			Algae : coral ratio	0.05	0.23
			Parrotfish density (ind. 100 m^{-2})	4.37	2.62
			Grouper density (ind. 100 m^{-2})	0.67	0.43

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Palawan / North Borneo** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	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)
	EN	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, which is mainly driven by C2. Based on historical declines and present conditions alone, the status is EN (driven by Criterion D).
- This ecoregion holds the largest mapped reef area in the region (7,926 km^2).
- Criterion A is LC (8.6%). Criterion B is LC.
- C1 is VU.
- Criterion D is EN. Hard coral cover declined from 52.2% to 30.4% (NT). Declines in parrotfish (4.37 to 2.62 ind. 100 m^{-2}, VU) and groupers (0.67 to 0.43 ind. 100 m^{-2}, EN) drove the final risk status under this criterion.

Recommendations:

- Curb destructive fishing practices and expand effective no-take protection across the ecoregion.
- Reduce sedimentation from logging and mining.

17 - Eastern Philippines - Critically Endangered (CR)

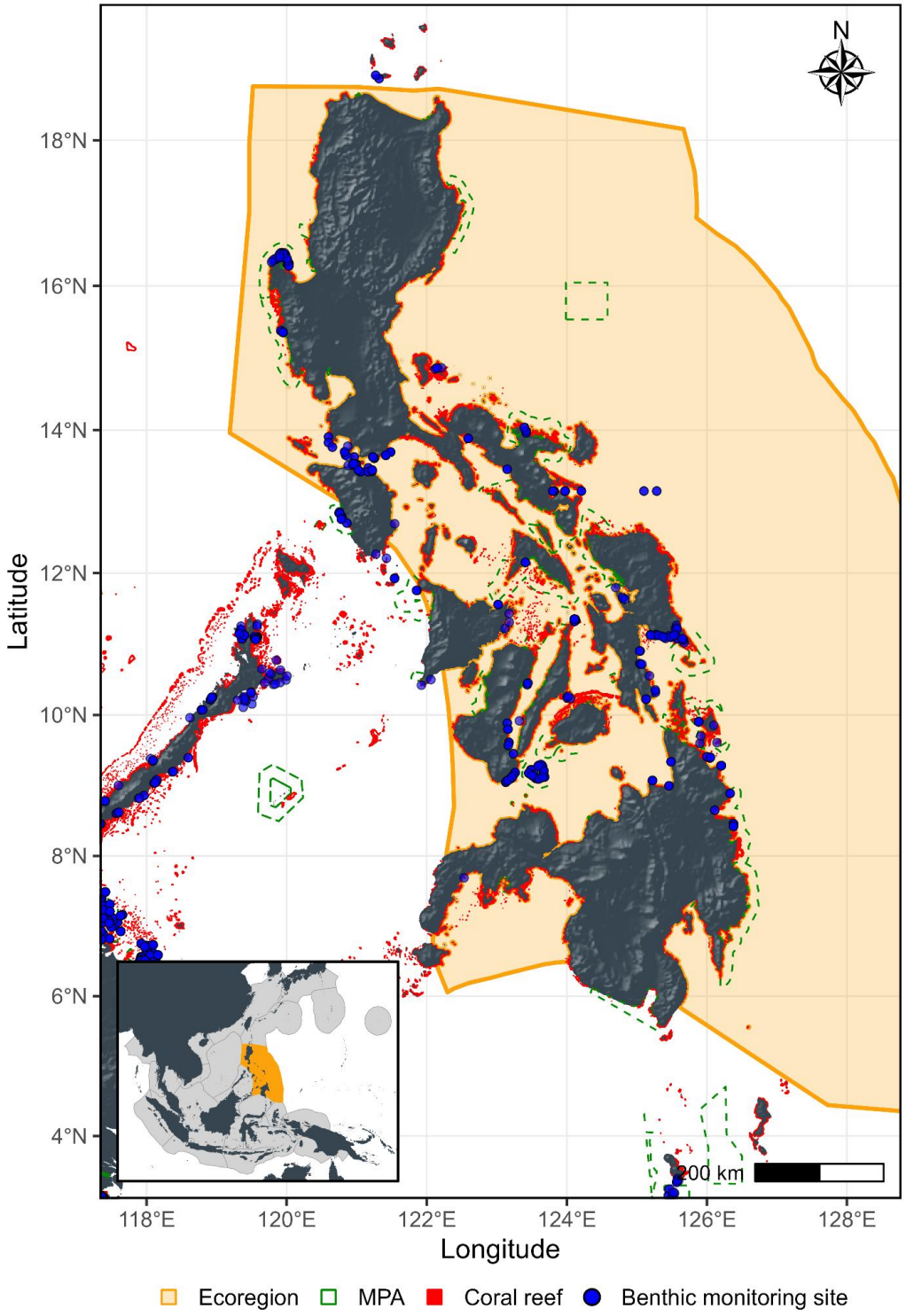


Figure 33 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Eastern Philippines ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Eastern Philippines coral reef ecoregion extends between 4.28°N and 18.74°N, 119.19°E and 129.92°E. It contains 24,319 km coastline, and 119,770 km^2 surface area under 200 m depth (Green & Mous, 2008). It vastly covers the Philippine Sea to the east, narrow sections of the Babuyan Channel to the north, the West Philippine Sea, as well as most inland seas. It includes the majority of Philippine Islands including the whole of Luzon Island, most of the Visayan islands, and Mindanao Island, except Babuyan Islands and Batanes, southwestern part of Mindoro Island and Panay Island, western part of Zamboanga Peninsula and Basilan Island, and southern tip of Mindanao Island facing Celebes Sea (South Cotabato towards Sarangani). Based on the UNEP-WCMC coral reef extent layer, the total reef area enclosed in this ecoregion is approximately 4,862.3 km^2.

Ecosystem description

This region harbours approximately 583 scleractinian (hard) coral species (Veron et al., 2015). Coral reefs here are subject to the influence of seasonal monsoons (Licuanan et al., 2019). The highly archipelagic environment supports diverse habitats and rich coral communities (Devantier & Turak, 2017; Licuanan et al., 2019). The central Philippines (located within this ecoregion) is also an area with the highest diversity of marine invertebrates and shore fish (Carpenter and Springer 2005). Reefs in the region are threatened by Illegal, Unreported and Unregulated (IUU) fishing (Acevedo et al., 2026), rapid urbanization and proximity to population centers (Heery et al., 2018), as well as plastic pollution and marine debris (Gomez et al., 2023; Liu et al., 2024).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
27.3%	686,999.72	1174	Hard coral cover (%)	22.8	23.2
			Algae : coral ratio	0.29	0.23
			Parrotfish density (ind. 100 m^{-2})	4.37 *	4.02
			Grouper density (ind. 100 m^{-2})	0.67 *	1.22

* Baselines for parrotfish and grouper borrowed from the Palawan / North Borneo ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in the **Eastern Philippines** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	NT	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)
	NT	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		

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

Key findings and recommendations

Key findings:

- Overall status CR across all criteria, which is mainly driven by C2. Based on historical declines and present conditions alone, the status is NT (driven by criteria A, C1 and D).
- Criterion A is NT (27.3%). Criterion B is LC.
- C1 is NT.
- Criterion D is NT. Hard coral cover is stable but comparatively low (22.8% to 23.2%), while parrotfish and grouper densities are close to or above baselines borrowed from the adjacent Palawan/North Borneo ecoregion.

Recommendations:

- Monitor typhoon impacts and establish local fish reference sites.
- Curb destructive fishing practices.
- Reduce pollution and marine debris.

18 - Sulawesi Sea / Makassar Strait - Critically Endangered (CR)

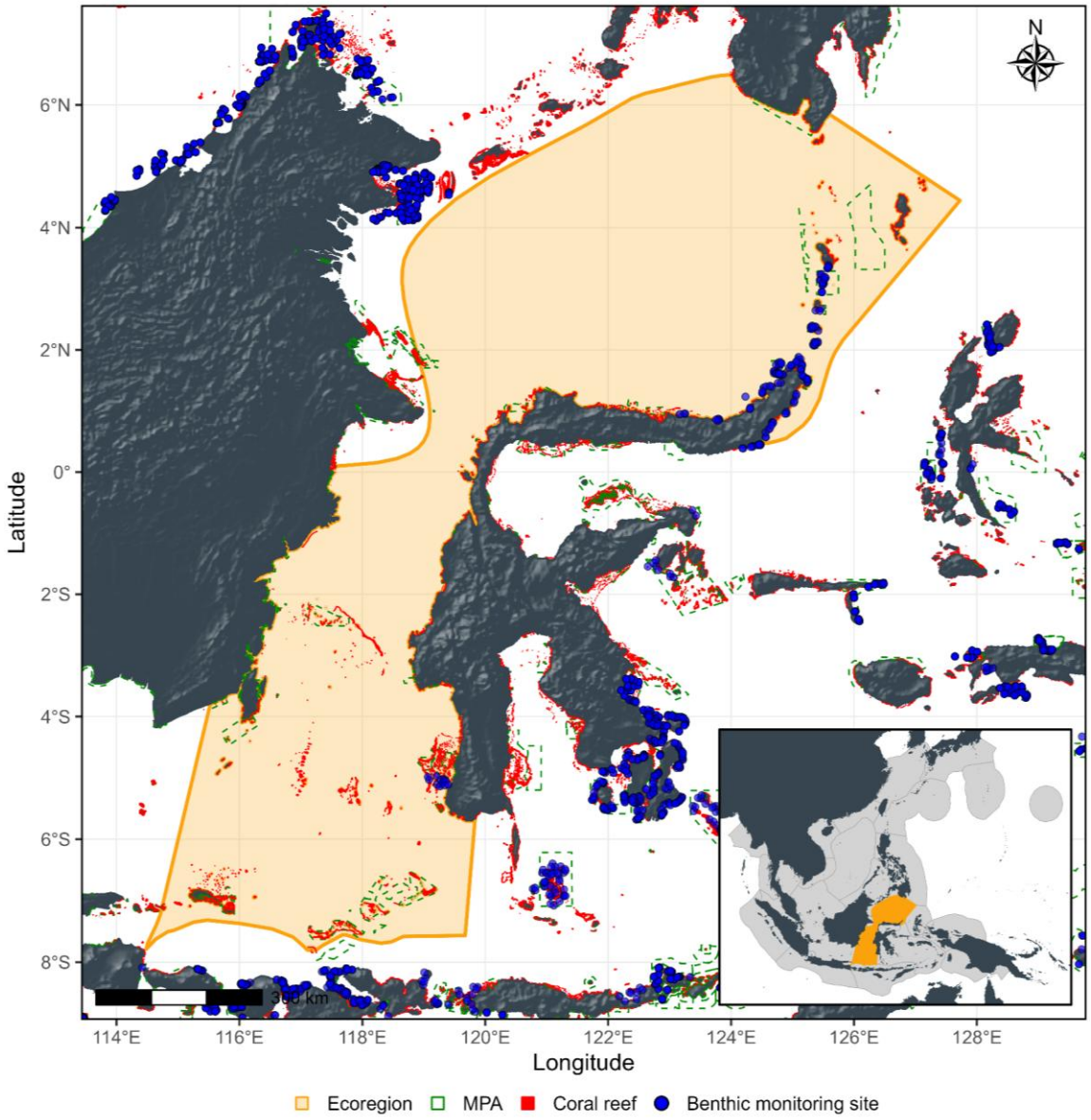


Figure 34 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Sulawesi Sea / Makassar Strait ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Sulawesi Sea/Makassar Strait coral reef ecoregion extends between 7.80°S and 6.49°N, 114.48°E and 127.73°E. It contains 10,035 km of coastline, and 158,140 km^2 of surface area shallower than 200 m (Green & Mous, 2008), and contains approximately 3,004.6 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). This ecoregion encompasses the following: the southern tip of Mindanao Island to the Talaud island chain in the north and north Sulawesi coastline, the Celebes Sea basin, the coasts of East-South Kalimantan and West-South Sulawesi, the Makassar Strait southwards to Kangean and the Tengah Islands.

Ecosystem description

This region harbours approximately 583 scleractinian (hard) coral species (Veron et al., 2015). The Indonesian Throughflow (ITF) is a key abiotic driver of reef dynamics in the region, which facilitates the movement of water from the Pacific into the Indian Ocean, mainly passing through the Makassar Strait and thereby cooling and bringing freshwater to the Indian Ocean, and enhancing larval connectivity (Huffard et al., 2012; Wang et al., 2026). Consequently, this ecoregion contains upwelling areas, and high diversity of both nearshore and offshore habitats (Green & Mous, 2008), in turn supporting high coral and fish species diversity (Allen, 2008; Veron et al., 2015), and hosting ecologically features such as important cetacean migration routes and rare fish species like the coelacanth (*Latimeria menadoensis*) (Green & Mous, 2008). Regional threats include coral bleaching, overfishing and marine debris (Liu et al., 2024).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
0.6%	956,387.63	606	Hard coral cover (%)	52.2 *	47.1
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	4.37 *	4.86
			Grouper density (ind. 100 m^{-2})	0.67 *	0.49

* Baselines for hard coral, parrotfish and grouper were borrowed from the Palawan / North Borneo ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Sulawesi Sea / Makassar Strait** was assessed as **Critically Endangered (CR).**

Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
	LC	LC	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1970)	Future or any 50y period	Historical (1750)
	NT	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		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, which is mainly driven by C2. Based on historical declines and present conditions alone, the status is VU (driven by criterion D).
- Criterion A is LC (0.6%). Criterion B is LC.
- C1 is NT.
- Criterion D is VU, driven by declines in groupers (0.67 to 0.49 ind. 100 m^{-2}). Hard coral cover (52.2% to 47.1%) is LC and parrotfish trends were evaluated as NT. All baselines were borrowed from the adjacent Palawan/North Borneo ecoregion.

Recommendations:

- Establish local reference sites.
- Reduce destructive fishing practices and marine debris.

19 - Halmahera - Critically Endangered (CR)

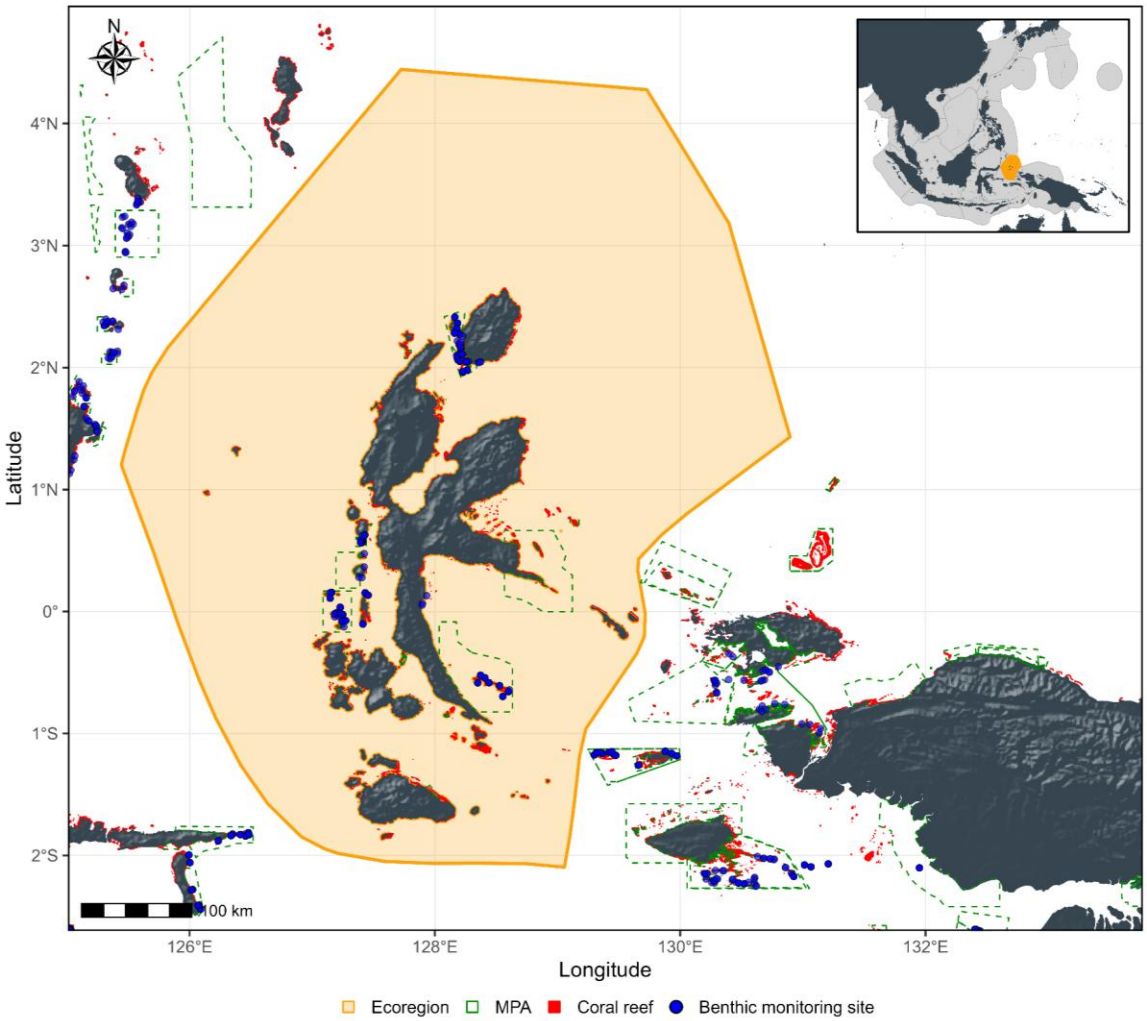


Figure 35 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Halmahera ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Halmahera coral reef ecoregion extends between 2.10°S and 4.44°N, 125.44°E and 130.90°E, consisting of 5,203 km of coastline, and 30,800 km^2 surface area shallower than 200 m (Green & Mous, 2008). It comprises the waters covering Halmahera and surrounding islands in North Maluku, and covers approximately 542.3 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer).

Ecosystem description

This ecoregion harbours approximately 587 scleractinian (hard) coral species (Veron et al., 2015) and contains highly complex habitats with leeward reefs and sites open to Pacific swells and several volcanic islands and underwater seamounts (Green & Mous, 2008; Huffard et al., 2012). The Indonesian Throughflow (ITF) is a major abiotic driver, and several

resulting upwelling sites contribute to high diversity. The presence of currents and upwelling brings cool water to the surface layers and may mitigate heat stress (Huffard et al., 2012). As part of the continuum of the Sulu-Sulawesi Sea, this ecoregion has high coral and fish species diversity (>1600 spp.) and endemicity (Huffard et al., 2012), as well as the highest per unit richness of corals (DeVantier & Turak, 2017). Some notable threats are IUU fishing, coastal mining, and eutrophication resulting in harmful algal blooms (HABs, Huffard et al., 2012).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
0%	121,574.7	238	Hard coral cover (%)	-	-
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	-	-
			Grouper density (ind. 100 m^{-2})	-	-

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Halmahera** was assessed as **Critically Endangered (CR).** Summary of the assessment:

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

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

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

Key findings and recommendations

Key findings:

- Overall status CR across all criteria, driven by sub-criterion C2. Based on historical declines and present conditions alone, the status is NT (driven by criterion C1).
- Criterion A is LC, with no site below 10% hard coral cover. Criterion B is LC.
- C1 is NT, possibly reflecting upwelling that buffers heat stress.
- Criterion D is DD, as no hard coral baseline could be defined and no fish monitoring data were available.

Recommendations:

- Expand benthic and fish monitoring to evaluate the biotic disruption and thus resolve Data Deficient status under Criterion D.
- Prioritise protection given the low observed heat stress and exceptional biodiversity.
- Address coastal mining and eutrophication.

20 - Papua - Critically Endangered (CR)

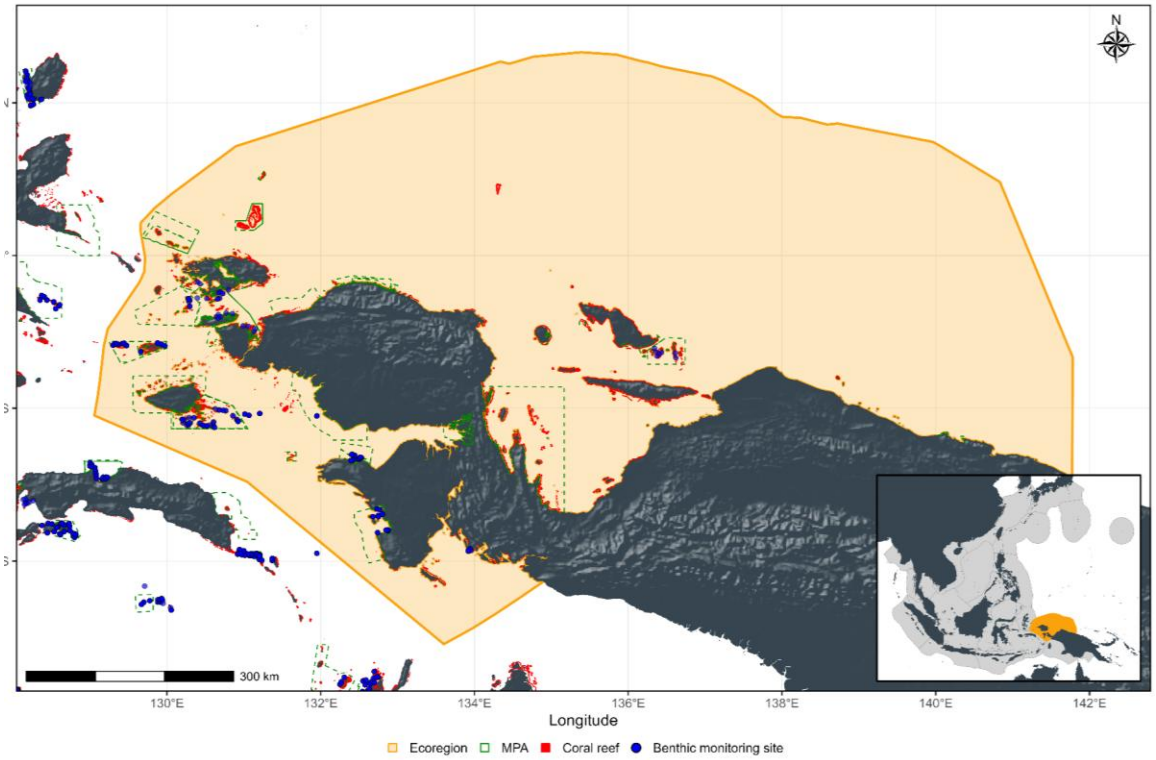


Figure 36 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Papua ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Papua coral reef ecoregion extends between 5.08°S and 2.66°N, 129.06°E and 141.78°E, and contains 18,284 km of coastline, 102,009 km^2 of surface area shallow than 200 m (Green & Mous, 2008), corresponding to approximately 2,064.3 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). It comprises the waters covering the northwest coast of Papua and surrounding islands.

Ecosystem description

This ecoregion harbours approximately 591 scleractinian (hard) coral species (Veron et al., 2015). It experiences high sea surface temperature variability (up to 16 °C) and thus may select for species tolerant of temperature variations (Huffard et al., 2012). It is also a transition zone between the Pacific Ocean and Indonesian seas, with the South Equatorial Current flowing westwards and merging into the Halmahera Eddy (Green & Mous, 2008). Habitat diversity is high, and includes mangroves, lagoons and marine lakes, karst channels and various reef types (Huffard et al., 2012). Correspondingly, this ecoregion has the highest fish diversity in the Coral Triangle (~1700 spp.; Allen, 2008). Several organisms of high endemicity are found in relative abundance here, spanning a range of taxa. Examples include leatherback turtles, reef sharks, mobulids, Napoleon wrasse, various cetaceans and dugongs

(Huffard et al., 2012). Despite low population pressure and relatively pristine and remote conditions, documented threats include destructive fishing, habitat degradation from mining, resource exploitation and unregulated coastal development (Huffard et al., 2012; Paulangan et al., 2019).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
9.8%	389,931.27	454	Hard coral cover (%)	54.5 *	32.8
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	28.14	8.52
			Grouper density (ind. 100 m^{-2})	4.6	0.92

* Baselines for hard coral were borrowed from the Lesser Sunda ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Papua** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	LC	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)
	EN	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, mainly driven by C2. Based on historical declines and present conditions alone, the status is EN (driven by criterion D).
- Criterion A is LC (9.8%). Criterion B is LC. C1 is LC, even with DHW thresholds set 1 DHW below those supported by bleaching records.
- Criterion D is EN. Hard coral cover declined from 54.5% (borrowed from Lesser Sunda) to 32.8% (NT), while parrotfish (28.14 to 8.52 ind. 100 m^{-2}, EN) and groupers (4.60 to 0.92 ind. 100 m^{-2}, CR) declined strongly from the highest baselines in the region.

Recommendations:

- Maintain the Raja Ampat MPA network and extend effective protection across the ecoregion.
- Reduce threats from coastal mining and unregulated development.

21 - Banda Sea - Critically Endangered (CR)

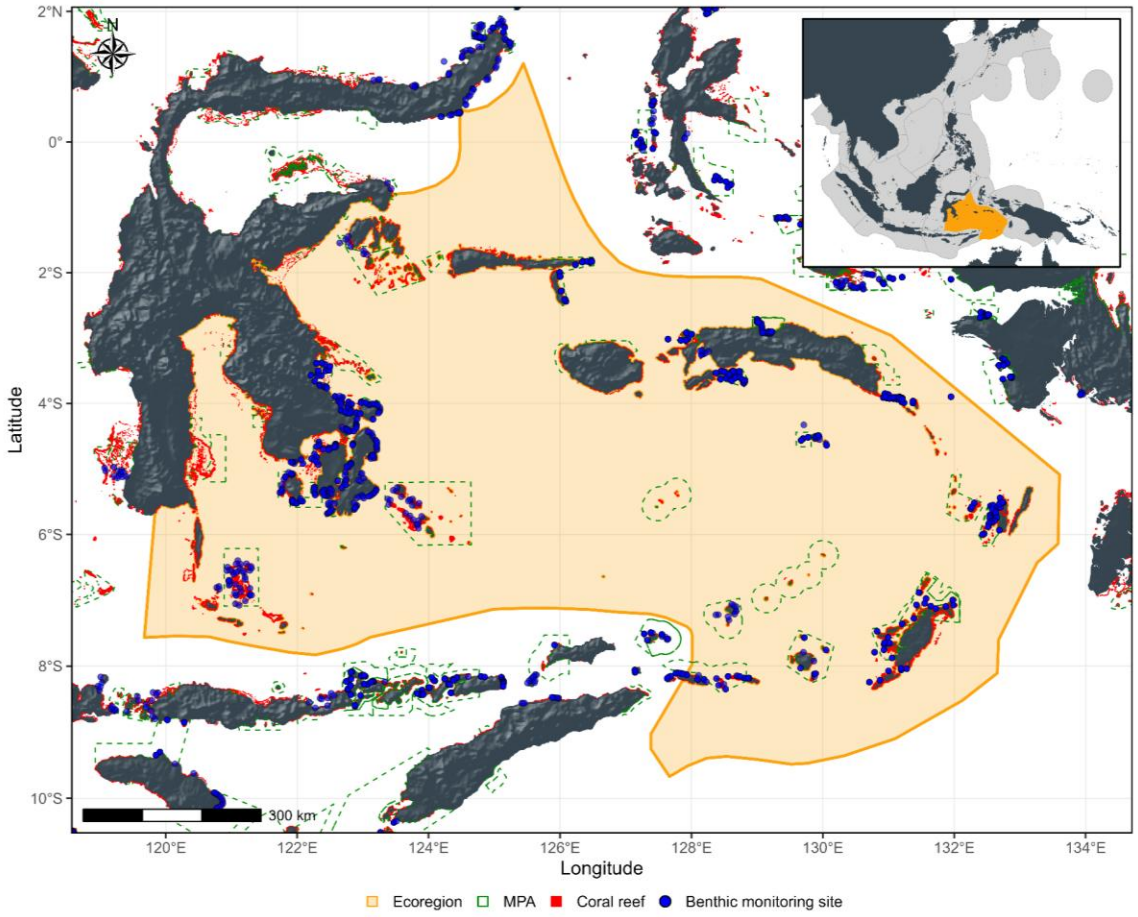


Figure 37 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Banda Sea ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Banda Sea coral reef ecoregion extends between 9.67°S and 1.20°N, 119.67°E and 133.60°E, and contains approximately 5,629.5 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). The Banda Sea has an estimated 15,380 km of coastline and 88,400 km^2 of shelf area shallower than 200 m (Green & Mous, 2008). It covers the Banda Sea and surrounding islands, bounded by south-eastern Sulawesi to the west, Taliabu, Buru and Seram islands to the north, and the Kei Islands to the east.

Ecosystem description

The Banda Sea coral reef ecoregion harbours approximately 591 scleractinian (hard) coral species (Veron et al., 2015), situated in a highly heterogeneous, tectonically active oceanic setting that appears to have partially mitigated thermal impacts on its reefs. Relative to the rest of the Coral Triangle, the ecoregion shows high reef fish species richness (>400 species; Allen, 2008) and very high coral species richness (Veron et al., 2015). Habitat heterogeneity

is extreme and spans from coastal reefs to isolated oceanic environments, with depths exceeding 5,000 m, strong upwelling and downwelling cells, and a volcanically active basin (Green & Mous, 2008; Huffard et al., 2012). Strong isolation of oceanic sites may have driven high endemicity, and upwelling events are thought to have mitigated thermal stress mortality during mass coral bleaching events (Huffard et al., 2012). The dominant current threats are destructive fishing practices and pollution (Setyawan et al., 2018). The combination of oceanographic isolation, deepwater habitats, volcanic activity, thermal buffering by upwelling and persistent destructive fishing pressure creates ecological dynamics unique to the Banda Sea ecoregion.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
10.6%	975,237.3	922	Hard coral cover (%)	54.5 *	36.6
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	28.14 *	1.94
			Grouper density (ind. 100 m^{-2})	4.6 *	0.29

* Baselines for hard coral were borrowed from the Lesser Sunda ecoregion, while those for parrotfish and groupers were borrowed from Papua.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Banda Sea** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	**A1**	**A2**	**A3**
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	**NE**	**NE**
B. Restricted Geo. Distribution	**B1**	**B2**	**B3**
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	**LC**	**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)
	LC	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		

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

Key findings and recommendations

Key findings:

- Overall status CR across all criteria, driven by C2. Based on historical declines and present conditions alone, the status is EN, driven by D.
- Criterion A is LC (10.6%). Criterion B is LC.
- C1 is VU.
- Criterion D is EN. Hard coral cover declined from 54.5% to 36.6% (NT), while parrotfish (28.14 to 1.94 ind. 100 m^{-2}) and groupers (4.60 to 0.29 ind. 100 m^{-2}) are both CR, relative to baselines borrowed from Papua.

Recommendations:

- Establish local fish reference sites, as borrowed baselines may overestimate declines.
- Curb destructive fishing practices and overfishing.
- Protect upwelling-influenced reefs as they may function as potential thermal refuges.

22 - Lesser Sunda - Critically Endangered (CR)

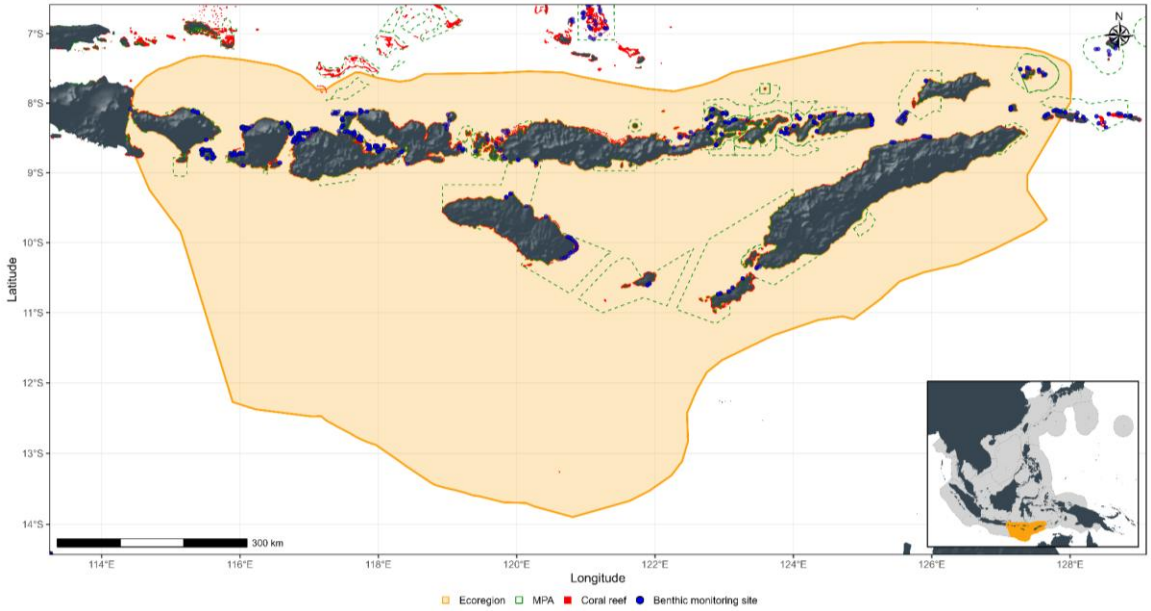


Figure 38 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Lesser Sunda ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Lesser Sunda coral reef ecoregion extends between 13.90°S and 7.12°S, 114.34°E and 128.01°E, and contains 10,886 km of coastline, and 40,812 km^2 of surface area shallower than 200 m (Green & Mous, 2008), corresponding roughly to the southwestern edge of Coral Triangle. Based on the UNEP-WCMC coral reef extent layer, this ecoregion contains approximately 949.6 km^2 of coral reefs.

Ecosystem description

The Lesser Sunda ecoregion harbours approximately 578 scleractinian (hard) coral species (Veron et al., 2015). It experiences seasonal upwellings (Wirasatriya et al., 2023), and experiences higher wave energy along southern than northern coasts (DeVantier et al., 2008). Hydrodynamic forcing from sources such as currents and tides drives nutrient mixing, larval dispersal, and reef connectivity, while upwelling zones enhance productivity and influence coral distribution and growth (DeVantier et al., 2008). This ecoregion displays a high rate of endemism and hosts more than 1,700 fish species (Allen, 2008). Recorded threats in this region include destructive fishing practices, overfishing, pollution, coastal development, increased SST, overtourism, sea level rise and ocean acidification.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
4.6%	535,467.46	502	Hard coral cover (%)	54.5	35.3
			Algae : coral ratio	0.08	0.16
			Parrotfish density (ind. 100 m^{-2})	28.14 *	5.31
			Grouper density (ind. 100 m^{-2})	4.6 *	0.19

* Baselines for parrotfish and groupers were borrowed from the Papua ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Lesser Sunda** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	LC	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)
	EN	NE	NE
E. Quantitative Risk analysis	NE		
OVERALL RISK CATEGORY	CR		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, which is mainly driven by C2. Based on historical declines and present conditions alone, the status is EN (driven by criterion D).
- Criterion A is LC (4.6%). Criterion B is LC.
- C1 is LC, even with DHW thresholds set 1 DHW below those supported by bleaching records.
- Criterion D is EN. Hard coral cover declined from 54.5% to 35.3% (NT). Parrotfish (EN) and groupers (4.60 to 0.19 ind. 100 m^{-2}, CR) declined strongly relative to baselines borrowed from Papua.

Recommendations:

- Derive local fish baselines from long-established MPAs such as Komodo National Park.
- Strengthen the enforcement of fisheries rules within existing MPAs.
- Reduce pollution and curb impacts from coastal development.

23 - Northeast Sulawesi - Critically Endangered (CR)

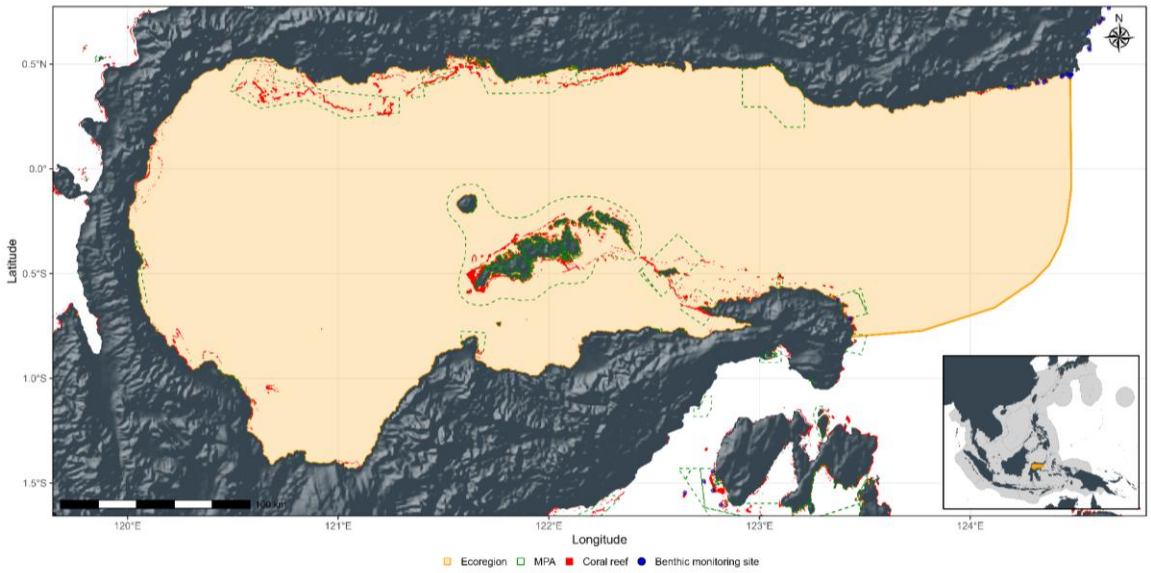


Figure 39 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Northeast Sulawesi. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Northeast Sulawesi coral reef ecoregion extends between 1.43°S and 0.55°N, 120.00°E and 124.48°E, and contains 2,556 km of coastline, and 25,356 km^2 surface area shallower than 200 m (Green & Mous, 2008). It consists of the waters in the Gulf of Tomini surrounded by the Central and North Sulawesi peninsula, with Togean Islands in the center. This corresponds to approximately 286.6 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer).

Ecosystem description

This region harbours approximately 576 scleractinian (hard) coral species (Veron et al., 2015) and contains a range of environments, ranging from various reef types within contiguous systems (Green & Mous, 2008), to deep bathymetry up to 3,000 m deep with several upwelling sites (Rositasari et al., 2023). Sporadic patches of fringing reef are associated with peninsulas, while the inner bay environment supports high larval connectivity across reefs (Green & Mous, 2008). As a component of the Coral Triangle, this ecoregion contains very high coral species richness (Veron et al., 2015) and high fish species richness (1577 spp.; Allen, 2008). It is threatened by destructive fishing, mining, overfishing, COTS outbreaks, sedimentation, and pollution (Moore & Ndobe, 2008).

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
0%	76,011.03	131	Hard coral cover (%)	52.2 *	52.3
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	28.14 *	2.6
			Grouper density (ind. 100 m^{-2})	4.6 *	0.4

* Baselines for hard coral were borrowed from the Palawan / North Borneo ecoregion, while those for parrotfish and groupers were borrowed from Papua.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Northeast Sulawesi** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	LC	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	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		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, driven by C2. Based on historical declines and present conditions alone, the status is VU (driven by criteria C1 and D).
- Criterion A is LC (0%). Criterion B is LC.
- C1 is VU.
- Criterion D is VU. Hard coral cover is stable (small average changes from 52.2% to 52.3%), while parrotfish (28.14 to 2.60 ind. 100 m^{-2}) and grouper (4.60 to 0.40 ind. 100 m^{-2}) declines relative to baselines borrowed from Papua, were evaluated as EN.

Recommendations:

- Monitor thermal stress and bleaching within the semi-enclosed bay that characterizes this ecoregion.
- Curb destructive fishing, mining and pollution, and manage COTS outbreaks.
- Establish local fish reference sites.

24 - Gulf of Papua - Critically Endangered (CR)

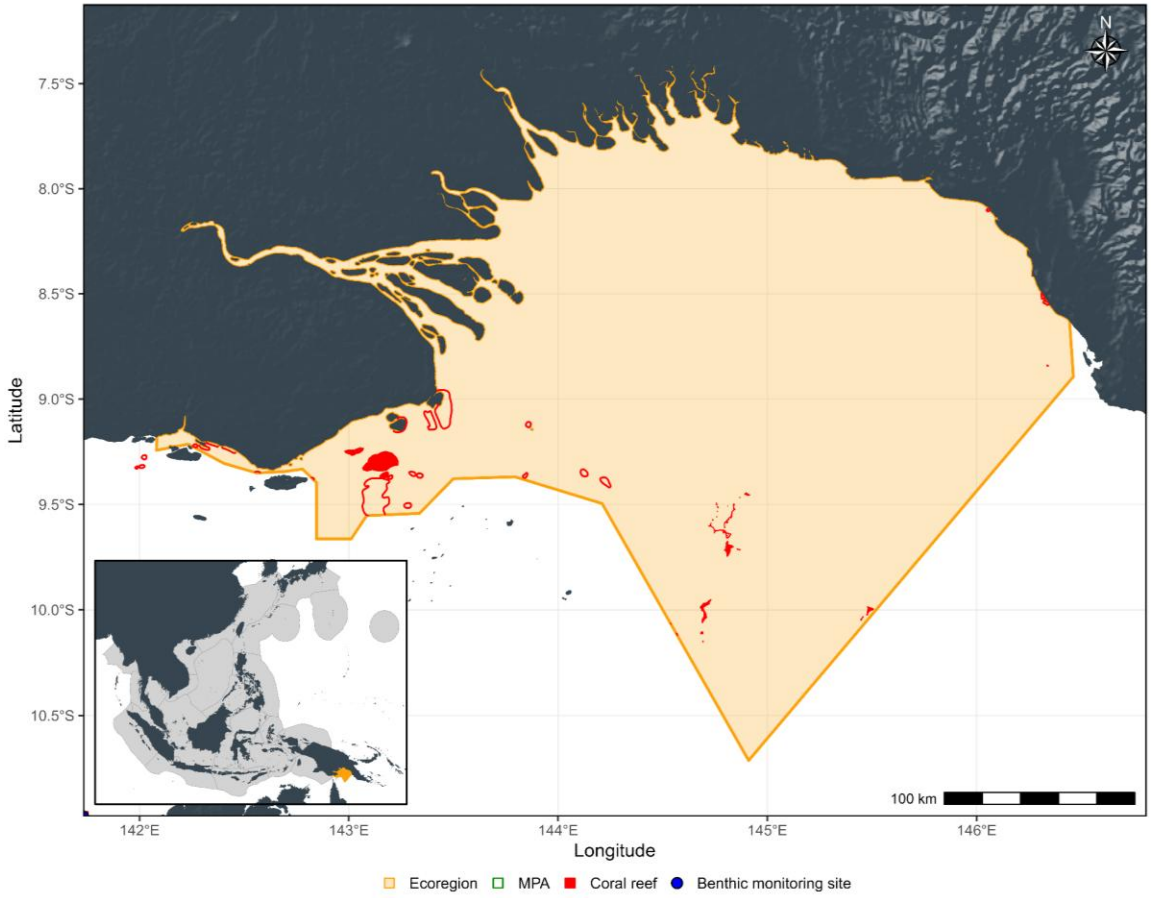


Figure 40 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Gulf of Papua ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Gulf of Papua coral reef ecoregion extends between 10.71°S and 7.39°S, 142.08°E and 146.46°E, and contains approximately 385.2 km^2 of coral reef (based on the UNEP-WCMC coral reef extent layer). The Papuan Barrier Reef lies to the east in the Milne Bay ecoregion and the northern Great Barrier Reef lies to the south-west. Most of the coastline is dominated by mangrove swamps with only sparse narrow fringing reefs (Veron et al., 2015).

Ecosystem description

The Gulf of Papua ecoregion harbours approximately 441 scleractinian (hard) coral species (Veron et al., 2015). It is a low-reef-development setting bordered by major reef systems on either side. Coral communities are developed on hard substrates and rubble banks away from the main influence of the Fly River, and waters are mostly clear offshore but turbid nearshore (Veron et al., 2015). Mixing and freshwater discharge from river systems has also been suggested as an explanation for observed patterns in fish assemblages found there. (Wolanski et al., 1984).

This ecoregion has also been identified as a potentially important habitat for several highly threatened elasmobranch taxa (Grant et al., 2021), which are threatened by both small scale, targeted fishing (Grant et al., 2021), and commercial trawling, with the latter representing a potentially growing threat as there is capacity for more extensive fisheries development in the region (Baje et al., 2021). The combination of mangrove-dominated coastlines, sparse narrow fringing reefs, river-influenced inshore turbidity and coral communities restricted to rubble banks and hard substrates away from major rivers creates ecological dynamics unique to the Gulf of Papua ecoregion.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km²)	AOO		Baseline	Current
-	55,778.24	48	Hard coral cover (%)	-	-
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	28.14 *	5
			Grouper density (ind. 100 m^{-2})	4.6 *	0

* Baselines for parrotfish and groupers were borrowed from the Papua ecoregion.

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Gulf of Papua** was assessed as **Critically Endangered (CR).** Summary of the assessment:

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

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

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, driven by sub-criteria C1 and C2. Based on historical declines and present conditions alone, the status is also CR.
- Criterion A is DD, as no benthic data was available for this ecoregion. Criterion B is VU (AOO 48).
- C1 is CR.
- Criterion D is DD because hard coral cover trends could not be assessed. Parrotfish declined (EN), and groupers were almost absent in recent surveys (mean 0.00 ind. 100 m^{-2} at seven sites), classifying this indicator as Collapsed (CO). These results should be verified in the field.

Recommendations:

- Establish benthic monitoring sites to resolve Data Deficient status under Criteria A and D.
- Verify the apparent absence of groupers through targeted and replicated fish surveys.

25 - Arafura Sea - Critically Endangered (CR)

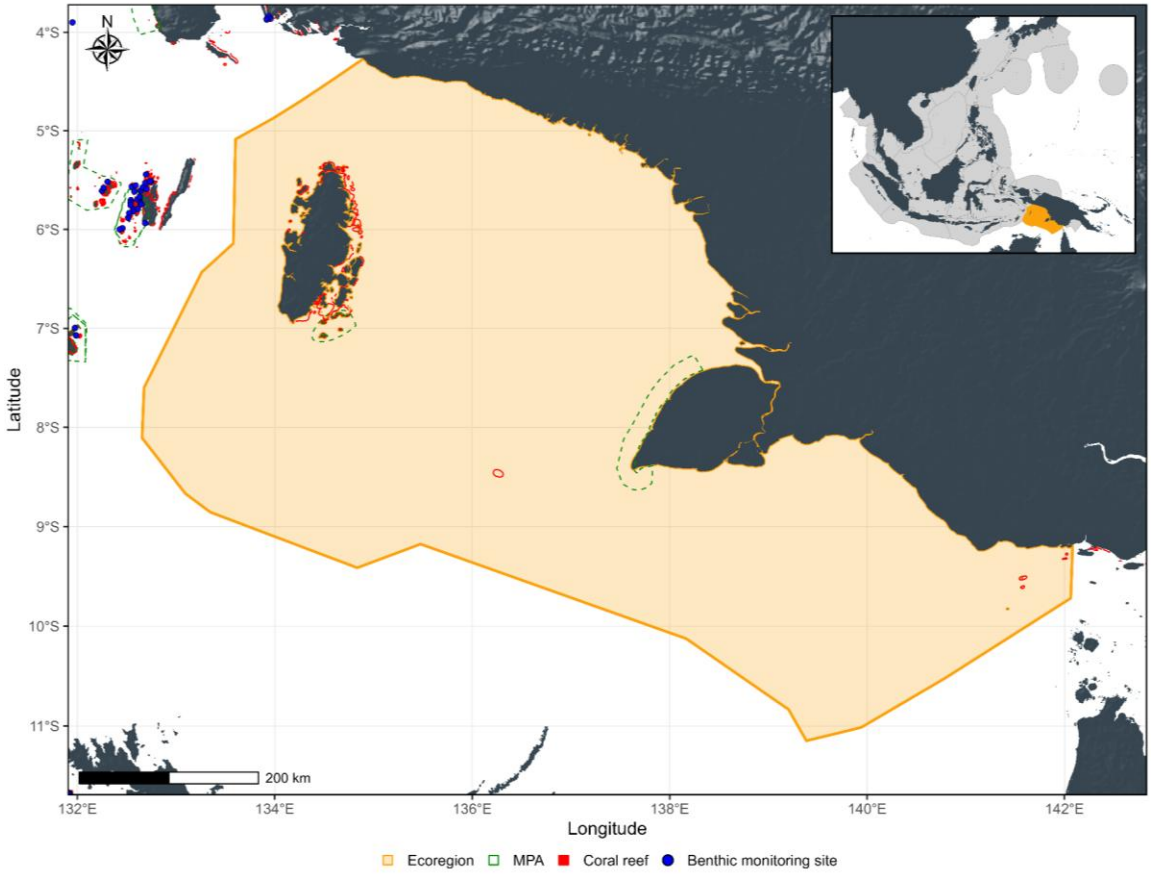


Figure 41 | Map of coral reef distribution (red), benthic monitoring sites (blue) and marine protected areas (green) of the Arafura Sea ecoregion. The inset shows the position of the ecoregion among the 25 ecoregions assessed in East Asia.

Spatial distribution

The Arafura Sea coral reef ecoregion extends between 11.15°S and 4.27°S, 132.66°E and 142.08°E, and contains approximately 430.2 km^2 of coral reef area (based on the UNEP-WCMC coral reef extent layer). The Arafura Sea occupies the waters below central and southern Papua, including the Aru Islands, and is not included within the Coral Triangle (Veron et al., 2015). Coral reef areas within the ecoregion are very limited and concentrated in the Indonesian sector (Alongi et al., 2011; Edyvane et al., 2024).

Ecosystem description

The Arafura Sea ecoregion harbours approximately 270 scleractinian (hard) coral species (Veron et al., 2015). It is a shallow, semi-enclosed tropical shelf sea sitting immediately outside the Coral Triangle. Coral species richness is lower than in the rest of the Coral Triangle (Veron et al., 2015), but the ecoregion has a substantial regional importance for rays, sawfishes, cetaceans, dugongs and turtles (Edyvane et al., 2024). The Arafura Sea is a shallow

(approximately 90 m) semi-enclosed sea, with high turbidity and sedimentation from multiple river inputs, and it contains extensive "near-pristine" mangrove, estuarine and coastal wetland habitats (Alongi et al., 2011). Its shallow, semi-enclosed form supports connectivity for pelagic and migratory species, and internal tides and shelf waves drive local monsoonal upwelling events that enhance productivity (Alongi et al., 2011; Edyvane et al., 2024). The ecoregion also serves as a potential biogeographic stepping stone between populations from Papua and Sulawesi and between Indonesian and Australian marine species (Huffard et al., 2012). Dominant threats include unsustainable fishing, poaching, and terrestrial runoff and sedimentation from land-based activities (Alongi et al., 2011). The combination of low coral but high vertebrate biodiversity, extensive pristine non-reef habitats, river-driven turbidity and a stepping-stone biogeographic role creates ecological dynamics unique to the Arafura Sea ecoregion.

Key values

Proportion of coral reef lost over the last 50 years (Criterion A)	Distribution (Criterion B)		Biotic Indicator Values (Criterion D)		
	EOO (km^2)	AOO		Baseline	Current
-	151,888.47	70	Hard coral cover (%)	-	-
			Algae : coral ratio	-	-
			Parrotfish density (ind. 100 m^{-2})	-	-
			Grouper density (ind. 100 m^{-2})	-	-

Criteria Assessment

Overall, the risk of collapse of the coral reefs in **Arafura Sea** was assessed as **Critically Endangered (CR).** Summary of the assessment:

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	DD	NE	NE
B. Restricted Geo. Distribution	B1	B2	B3
	Extent of Occurrence	Area of Occupancy	# Threat-defined Locations < 5?
	LC	LC	NE

CRITERION			
A. Reduction in Geographic Distribution	A1	A2	A3
	Past 50 years	Future or any 50y period	Historical (1750)
	DD	NE	NE
C. Environmental Degradation	C1	C2	C3
	Past 50 years (1970)	Future or any 50y period	Historical (1750)
	EN	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		

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

Key findings and recommendations

Key findings:

- Overall status is CR across all criteria, which is mainly driven by C2. Based on historical declines and present conditions alone, the status is EN (driven by sub-criterion C1).
- Criteria A and D are DD, as no benthic and fish monitoring data were available.
- Criterion B is LC.
- C1 is EN.

Recommendations:

- Establish benthic and fish monitoring as a priority.
- Reduce terrestrial runoff, overfishing and poaching.