

From Risk to Application: What Critically Endangered means for the world's coral reefs

Mishal Gudka^{1,3}, David Keith², David Obura³, Ena L. Suárez⁴, Marcos Valderrábano⁴, Emily Nicholson¹

¹School of Agriculture, Food and Ecosystem Sciences, University of Melbourne, Melbourne, Australia

²Biological, Earth & Environmental Sciences, University of New South Wales, Sydney, Australia

³CORDIO East Africa, Mombasa, Kenya

⁴International Union for Conservation of Nature (IUCN), Gland, Switzerland

Abstract

The first global risk assessment of coral reef ecosystems has found all fully assessed, shallow-water (photic) coral reef ecosystems are at an extremely high risk of ecological collapse in the next 50 years. This *Critically Endangered* risk assignment under the Red List of Ecosystems (RLE) applies to 122 of the 127 coral reef ecosystems (ecoregions) and was assessed by regional expert teams, combining global datasets with local monitoring data and knowledge. The primary driver of risk is the frequency of marine heatwaves, projected to exceed tolerable limits within 50 years, even under a moderate climate scenario (IPCC SSP2-4.5). Even ecoregions that have shown resilience to warming and retained a relatively intact balance of corals, algae, and fish are at extremely high risk due to the elevated frequency of projected marine heatwaves.

The outlook is alarming, yet much of the risk stems from projected changes that have yet to fully materialise, providing a critical window to scale up conservation and climate efforts. A *Critically Endangered* outcome is an early warning that calls for an urgent response. This assessment provides an evidence base for policy on coral reef ecosystems. It identifies the need for clear and urgent actions that stakeholders can take to reduce risks to reefs and support their recovery at global, national, and local scales. The data and results can be used to strengthen legal protection for threatened ecosystems, reporting under the Kunming-Montreal Global Biodiversity Framework, and building climate resilience in dependent coastal communities. Importantly, this assessment highlights the urgent need for drastic emissions reduction. If coral reef ecosystems are to persist as we know them, strong local management and restoration must be underpinned by efforts to contain global warming as close as possible to 1.5°C.

Introduction

The first comprehensive, standardised, global risk assessment of coral reef ecosystems is complete, finding that **all fully-assessed shallow-water coral reef ecosystems are at an extremely high risk of ecological collapse in the next 50 years**. Coral reefs are integral for people, economies and biodiversity around the world, but the scientific evidence indicates a grim outlook (Bozec et al., 2025; Emslie et al., 2024; Intergovernmental Panel on Climate Change (IPCC), 2022; Mellin et al., 2024; Zeng et al., 2025), which demands urgent and strong actions to remedy their decline. Just as risk assessments have successfully informed measures that have rescued endangered species, they have the power to do the same for ecosystems.

This article places the critically endangered status of the world's coral reef ecosystems in context and outlines the urgency and scale of action required to safeguard them. The first-ever Global Red List of Coral Reef Ecosystems provides a policy-relevant foundation to drive

progress on emissions reductions, local stressor and sustainable reef management and stronger legal protection for threatened ecosystems.

The Red List of Ecosystems — Purpose and Principles

Assessing ecosystem collapse risk acts as an early warning that an ecosystem is in trouble to prompt action before the worst outcomes occur. The RLE provides a scientifically rigorous, repeatable, and standardised classification of this risk, from 'Least Concern' to 'Collapsed' based on symptoms of ecosystem decline. The threatened categories of Vulnerable, Endangered or Critically Endangered, respectively indicate increasing risks of collapse.

For coral reefs, collapse can result directly from lost area (e.g. through landfilling), but more generally, through continuous degradation due to disease, overharvesting, or a persistent change in environmental conditions. A collapsed coral reef is characterized by extremely low coral cover, richness and diversity, and is typically accompanied by a phase shift toward dominance by organisms such as turf and fleshy algae, or filter-feeding invertebrates – it has transformed into a different ecosystem type (Fig. 1). Various regional and ecoregional RLE assessments (Bland et al., 2017; Keith et al., 2013; Obura et al., 2022; Uribe et al., 2021) have set the stage to deliver global coverage of the collapse risk of all photic coral reef ecosystems.

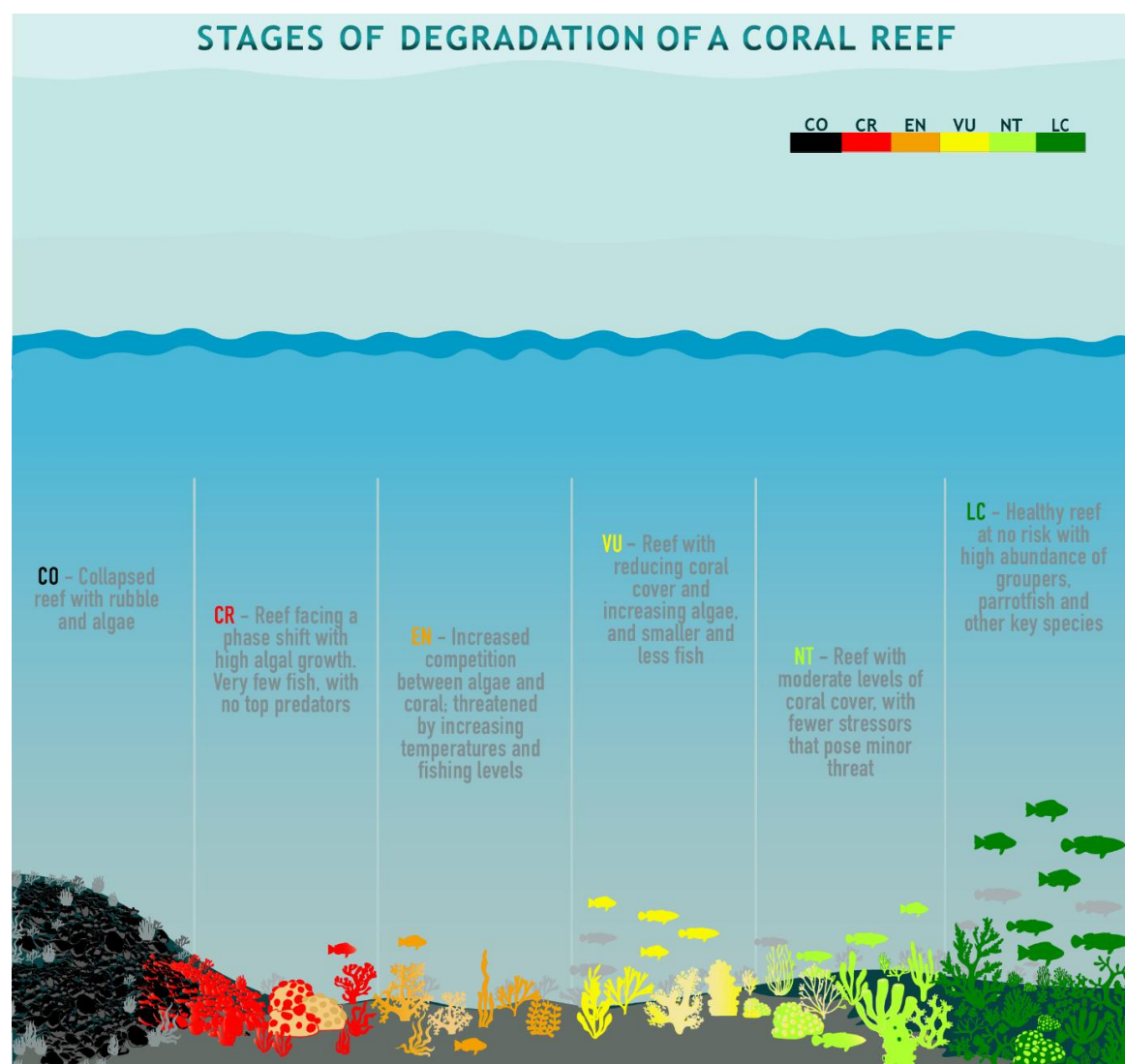


Figure 1. Stages of degradation of a coral reef ecosystem and associated risk classifications (CO – Collapsed, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern).

Unlike species extinction, which is final, some ecosystems may recover from collapsed states, so long as their native biodiversity persists somewhere and the pressures that drove them to collapse are effectively mitigated (Keith et al., 2015). For example some coral reefs in the Seychelles have demonstrated natural recovery after collapsing at local scales from disturbance events like bleaching (Robinson et al., 2019). However, this takes many years of undisturbed conditions and ecosystem composition and diversity may not fully return to its pre-collapse state. Recovery is also not guaranteed: in the Western Galápagos Islands, coral reefs lost almost all their corals (about 95% mortality) during the 1982–83 El Niño, and have since failed to recover. It is the only ecoregion already classified as Collapsed in this global assessment.

Interpreting the results of an RLE – an ecosystem perspective

It is important to stress that this assessment does not provide a reef-scale classification. The RLE takes an ecosystem perspective to capture trends, patterns and risks at a broader spatial scale. The ecosystem scale means that although fine-scale variation feeds into the risk assessment, the final status relates to the ecosystem as a whole, not to individual reefs or component species. In this assessment, key differences in biodiversity and environmental conditions resulted in coral reefs being split into 127 different ecosystems (or ecoregions), of which all reef ecosystems are Critically Endangered, with the exception of four with insufficient data for assessment and one that has already collapsed. The RLE also considers a range of factors and timeframes that could place an ecosystem at risk of collapse including the current and historic conditions, as well as future changes. Therefore, an ecosystem could still be relatively healthy today but still be at high risk because its environmental conditions are predicted to change drastically in the future.

Across all assessed ecoregions, the key driver of risk is the frequency of marine heat waves, which is projected to increase to beyond limits considered tolerable in the next 50 years under a moderate climate scenario (SSP2-4.5). This trend has already begun and the rate of warming is accelerating. 91% of coral reef ecoregions are already threatened (24% Critically Endangered, 42% Endangered and 25% Vulnerable) based on observed trends in heat stress and declines in corals, algae and fish. The scale and severity of coral bleaching during the third and fourth mass global bleaching events (in 2014-16 and 2023-25, respectively) were unprecedented (Eakin et al., 2026; NOAA NESDIS, 2026), and there is now the threat of the ‘super’ El Niño already approaching peak levels at the time of publication (Dinneen, 2026).

From Risk Signal to Response

Reframing Threatened Status to enable action

The alarming outlook for coral reefs due to climate change may create a sense of disengagement, fatalism, or policy paralysis. But a Critically Endangered or Endangered risk assessment outcome is not a death sentence, and rather a call to action at the highest level of urgency. Our assessment shows that much of the risk is driven by projected change(s) that have not yet fully materialised, and this provides a critical window to scale up conservation and climate efforts.

Beyond the headline categories, the assessment compiles reef maps verified and refined by each regional team, together with monitoring data, heat-stress analyses and projections for every coral reef ecoregion. Conservation and management efforts should leverage this wealth of data and diagnostics, alongside site-level and short-term assessment or predictions about resilience and bleaching response for effective decision making.

Management Responses in Threatened Ecosystems

The value of the RLE lies in the decisions and actions it enables and supports at various scales (Table 1) and across different stakeholders (Table 2). This includes:

- **Climate action:** With a cohesive global picture, this assessment tells us clearly that the environment that coral reefs inhabit is becoming increasingly hostile around the world due to climate change. It offers more evidence for the urgent transformative change required to keep global warming to 1.5°C and minimise the chances of complete coral reef loss (Intergovernmental Panel on Climate Change (IPCC), 2022; United Nations Environment Programme, 2026). This means **the window for effective action is narrowing**, and the cost of inaction is rising each year. Even ecoregions that have so far shown resilience to warming and a relatively intact balance of corals, algae and fish, such as the Northern Red Sea, Papua New Guinea, West Kiribati and Bermuda, are at extremely high risk, because without climate mitigation, projected warming is so extreme that it is uncertain whether corals can survive such uncharted stress levels.

Climate projections are too coarse in spatial resolution to capture localised features such as thermal refuges and resilient coral communities. If warming is effectively mitigated, even by a fraction of a degree, it can provide any pockets of resilient reefs the best chance to retain relatively high ecological integrity. Identifying and protecting these ‘bright spots’ should be a priority as these reefs will be critical to the persistence and recovery of threatened ecosystems (Greiner et al., 2022; Lin & Cinner, 2026; Zawada et al., 2026).

- **Conservation:** Although local actions are no substitute for climate change mitigation, and ultimately rely on it, they can buy time while greenhouse gas emission reduction takes its delayed effect. Climate impacts are often exacerbated by more localised stressors such as runoff of polluted, eutrophic or turbid waters, overfishing, invasive species or disease outbreaks (Donovan et al., 2021). The compounding effects of these local stressors can be mitigated, enhancing reef resilience by strengthening and expanding Marine Protected Areas (MPAs), improving fisheries management, reducing land-based pollution, and controlling invasive species.
- **Restoration:** Active coral and reef restoration (fragmentation, coral gardening, larval seeding), substrate stabilisation, and emerging approaches such as assisted gene flow and assisted evolution can support restoring ecological function and processes (Anthony et al., 2020; Chan et al., 2023; Yanovski & Abelson, 2019). However, restoration at scale remains challenging and resource-intensive, with ecological outcomes uncertain, and therefore should complement, not substitute actions that address the root causes of decline (Hein et al., 2021; Mulà et al., 2025; Vardi et al., 2021). Priorities should target ecoregions where biotic degradation of corals is high, but algae remain naturally low, herbivorous fish populations are well protected (Criterion D of the RLE), and ecoregions that have to date shown relative resilience to warming (sub-criterion C1 of the RLE). Approaches must focus on restoring ecosystems in addition to species objectives and be holistic to educate, empower and economically-support local communities, as well as enhance research and knowledge (Knoester et al., 2023).

- **National biodiversity policy:** This global assessment was built from the bottom-up by regional expert teams, who combined global datasets with local monitoring data and knowledge, giving regions ownership of the results. In Australia, Brazil and some South Asian countries, it can already serve as a national assessment to be directly applied by governments in legal and policy instruments (Bland et al., 2019; Keith et al., 2023). In addition, the RLE is adopted as a headline indicator (A.1) of the Kunming-Montreal GBF, meaning this assessment directly supports national reporting obligations under the Convention on Biological Diversity (Nicholson et al., 2024). In other regions, it provides the foundation for national assessments as the methodology, data frameworks, and regional context are already established, as has been done in the Western Indian Ocean (Gudka et al., 2024). Importantly, it also shows where monitoring data are missing, and where investment is required nationally to fill these gaps. The global assessment should therefore be seen as a catalyst and context for national assessments, making them faster, cheaper, and more policy relevant.
- **Regional and global applications:** The global assessment helps to identify transboundary priorities that require coordinated international responses. Trans-boundary and national risk results should support updates of resolutions in regional biodiversity and ocean conventions like UNEP Regional Seas, as well as national policy and legislation to prioritise action and protection of coral reefs. The global assessment provides a consistent standard for international reporting and comparison to target priority areas, and can be updated as new data emerge, national assessments are completed, or conditions change.
- **Coastal and social resilience:** Two collateral priorities follow the warning issued by our risk assessment results. First, protection of other coastal and marine ecosystems, such as seagrasses and mangroves, must be strengthened, along with sustainable fisheries management. This will help retain coastal resilience and ecosystem services as much as possible as they diminish from coral reefs. Second, large-scale investment is needed to build climate adaptation and resilience in the coastal people that depend on coral reefs. This includes establishing and formally recognising community-managed areas as Other Effective Area-based Conservation Measures (OECMs), and ensuring that support is delivered fairly and equitably, with local rights, knowledge and leadership at the centre of decision-making (Jonas et al., 2024).

Table 1. Policy and Management actions informed by various aspects of the Red List of Ecosystems (RLE) assessment of coral reefs, organised by scale (global, regional, national, local), with the key actors responsible for implementing each action.

Scale	Action	Actors	Informed by RLE
Global	Advocate for emissions reductions, loss and damage mechanisms and adaptation finance	Governments, UNFCCC negotiators, funders	Global picture showing conditions becoming increasingly hostile for reefs; emissions as the primary lever
Global	Raise the profile of coral reefs and build political and public will	Scientists, IUCN, NGOs, media	Consistent global assessment and risk categories

Scale	Action	Actors	Informed by RLE
Regional	Update resolutions in regional conventions (e.g. UNEP Regional Seas) to prioritise reefs and other threatened ecosystems	Regional bodies, member states	Regional risk results
Regional	Coordinate responses to transboundary priorities	Neighbouring countries, regional bodies	Transboundary risk patterns across ecoregions
Regional	Direct resilience investment to high-risk/high value regions	Funders, regional organisations	Ecoregion-level risk categories
National	Conduct national RLE assessments	Government agencies, national scientists	Global assessment as a starting point building on the global methodology and data
National	Embed threatened ecosystems in policy and legislation to afford higher protection	Governments, legislators	Risk category of ecosystems within national boundaries
National	Report on national obligations under the CBD Kunming-Montreal GBF	Environment ministries/ CBD Parties	RLE as GBF headline indicator
National	Strengthen protection of less climate-sensitive ecosystems (seagrasses, mangroves) and fisheries management	Governments, coastal and fisheries agencies	High collapse risk as early warning of declining reef services
Local	Expand and strengthen MPAs, reduce land-based pollution and other local stressors	Site managers, local authorities	Criterion D (high integrity sites)
Local	Invest in climate adaptation and resilience of dependent coastal communities	Governments, funders, development agencies, conservation practitioners	High collapse risk as early warning of declining reef services
Local	Identify and protect thermally tolerant, well-connected or resilient reef areas	Site managers, scientists	Criterion D (biotic degradation – areas with high coral cover); Sub-criterion C1 (relative resilience to warming)
Local	Active restoration (e.g. coral gardening, larval seeding), alongside action on root causes	Restoration practitioners, communities, Dive industry	Criterion D (biotic degradation, with low algae and protected herbivores); Sub-criterion C1

Scale	Action	Actors	Informed by RLE
Local	Establish and formally recognise community-managed areas as OECMs, with fair and equitable support	Local communities, governments, NGOs, Dive industry	High-risk regions and dependent communities

Conclusion

While confirming a universally high-risk prognosis for coral reef ecosystems worldwide, the first global Red List of coral reef ecosystems signals clear and imperative pathways for risk reduction and recovery. It is a rich source of information for exploring finer-scale trends, the drivers of risk and where action is most needed. Alongside complementary tools such as GCRMN, site-level resilience assessments, and coral species red lists, this RLE provides a globally consistent, policy-relevant foundation that has until now been missing from reef conservation.

The assessment underscores the need for local management interventions, even in the most threatened ecosystems; the question is not whether to act, but how to act most effectively given the risk profile each region faces. Last, but most importantly, this assessment highlights the urgent need for drastic emissions reduction. If the coral reefs of today are to persist as we know them, strong local management and restoration must be underpinned by efforts to contain warming as close as possible to 1.5°C.

Table 2. Key stakeholder groups and how they can interpret and apply the results of a Red List of Ecosystems (RLE) assessment for coral reefs

Audience	How to Use the RLE Results	Specific Applications
National governments	International biodiversity reporting obligations; designate and prioritise threatened ecosystems in national policy and legislation;	National Biodiversity Strategy and Action Plans (NBSAPs); national environmental legislation; MPA network design and expansion; GBF headline indicator A.1 reporting; national RLE assessments
Regional bodies and conventions	Identify transboundary priorities; coordinate management; Update resolutions in regional conventions to increase/prioritise threatened ecosystems	Regional fisheries and biodiversity bodies (e.g., ROPME, SPREP, PERSGA); UNEP Regional Seas Conventions; transboundary MPA planning;
Conservation NGOs	Target restoration and conservation investment. Use the RLE criteria to diagnose which threats drive risk	Site prioritisation, fundraising, threat-specific conservation programmes; evidence-based fundraising and advocacy;

Audience	How to Use the RLE Results	Specific Applications
Local managers and coastal communities	Reduce local pressures; strengthen community-based management	Small-scale fisheries co-management, no-take areas, pollution control, Other Effective Area-Based Conservation Measures (OECMs)
Dive tourism industry	Communicate reef status; support stewardship;	Reef health communication, sustainable tourism certification; market critical status and unique biodiversity to increase business
Funders and philanthropy	Allocate resources to highest-risk, highest-value reefs	Grant prioritisation, impact metrics; support national assessment
Private sector	Assess and disclose nature-related risks associated with reef-dependent operations; Avoid or mitigate impacts to endangered ecosystems; align with emerging nature-positive frameworks	Task Force on Nature-related Financial Disclosures (TNFD); Science Based Targets for Nature (SBTN); environmental impact assessment; sustainable supply chain management
Scientists	Identify data gaps; contribute to future assessment cycles	GCRMN data contribution, national RLE assessments
Educators and communicators	Create awareness about reef decline for public audiences	Responsible science communication

References

- Anthony, K. R. N., Helmstedt, K. J., Bay, L. K., Fidelman, P., Hussey, K. E., Lundgren, P., Mead, D., McLeod, I. M., Mumby, P. J., Newlands, M., Schaffelke, B., Wilson, K. A., & Hardisty, P. E. (2020). Interventions to help coral reefs under global change—A complex decision challenge. *PLOS ONE*, 15(8), e0236399. <https://doi.org/10.1371/journal.pone.0236399>
- Bland, L. M., Nicholson, E., Miller, R. M., Andrade, A., Carré, A., Etter, A., Ferrer-Paris, J. R., Herrera, B., Kontula, T., Lindgaard, A., Pliscoff, P., Skowno, A., Valderrábano, M., Zager, I., & Keith, D. A. (2019). Impacts of the IUCN Red List of Ecosystems on conservation policy and practice. *Conservation Letters*, 12(5), e12666. <https://doi.org/10.1111/conl.12666>
- Bland, L. M., Regan, T. J., Dinh, M. N., Ferrari, R., Keith, D. A., Lester, R., Mouillot, D., Murray, N. J., Nguyen, H. A., & Nicholson, E. (2017). Using multiple lines of evidence

- to assess the risk of ecosystem collapse. *Proceedings of the Royal Society B: Biological Sciences*, 284(1863), 20170660. <https://doi.org/10.1098/rspb.2017.0660>
- Bozec, Y.-M., Adam, A. A. S., Arellano-Nava, B., Cresswell, A. K., Haller-Bull, V., Iwanaga, T., Lachs, L., Matthews, S. A., McWhorter, J. K., Anthony, K. R. N., Condie, S. A., Halloran, P. R., Ortiz, J.-C., Riginos, C., & Mumby, P. J. (2025). A rapidly closing window for coral persistence under global warming. *Nature Communications*, 16(1), 9704. <https://doi.org/10.1038/s41467-025-65015-4>
- Chan, W. Y., Meyers, L., Rudd, D., Topa, S. H., & van Oppen, M. J. H. (2023). Heat-evolved algal symbionts enhance bleaching tolerance of adult corals without trade-off against growth. *Global Change Biology*, 29(24), 6945–6968. <https://doi.org/10.1111/gcb.16987>
- Dinneen, J. (2026). The super El Niño is cooking coral reefs—Can lullabies and probiotics save them? *Nature*, 658(8134), 22–24. <https://doi.org/10.1038/d41586-026-02965-9>
- Donovan, M. K., Burkepille, D. E., Kratochwill, C., Shlesinger, T., Sully, S., Oliver, T. A., Hodgson, G., Freiwald, J., & Woesik, R. van. (2021). Local conditions magnify coral loss after marine heatwaves. *Science*, 372(6545), 977–980. <https://doi.org/10.1126/science.abd9464>
- Eakin, C. M., Heron, S. F., Connolly, S. R., Devotta, D. A., Liu, G., Geiger, E. F., De La Cour, J. L., Gomez, A. M., Skirving, W. J., Baird, A. H., Cantin, N. E., Couch, C. S., Donner, S. D., Gilmour, J., Gonzalez-Rivero, M., Gudka, M., Harrison, H. B., Hodgson, G., Hoegh-Guldberg, O., ... Manzello, D. P. (2026). Severe and widespread coral reef damage during the 2014-2017 Global Coral Bleaching Event. *Nature Communications*, 17(1), 1318. <https://doi.org/10.1038/s41467-025-67506-w>
- Emslie, M. J., Logan, M., Bray, P., Ceccarelli, D. M., Cheal, A. J., Hughes, T. P., Johns, K. A., Jonker, M. J., Kennedy, E. V., Kerry, J. T., Mellin, C., Miller, I. R., Osborne, K., Puotinen, M., Sinclair-Taylor, T., & Sweatman, H. (2024). Increasing disturbance frequency undermines coral reef recovery. *Ecological Monographs*, 94(3), e1619. <https://doi.org/10.1002/ecm.1619>
- Greiner, A., Andreello, M., Darling, E., Krkošek, M., & Fortin, M.-J. (2022). Limited spatial rescue potential for coral reefs lost to future climate warming. *Global Ecology and Biogeography*, 31(11), 2245–2258. <https://doi.org/10.1111/geb.13571>
- Gudka, M., Obura, D., Treml, E., Samoilys, M., Aboud, S. A., Osuka, K. E., Mbugua, J., Mwaura, J., Karisa, J., Knoester, E. G., Musila, P., Omar, M., & Nicholson, E. (2024). Leveraging the Red List of Ecosystems for action on coral reefs through the Kunming-Montreal Global Biodiversity Framework. *Conservation Science and Practice*, 6(12), e13255. <https://doi.org/10.1111/csp2.13255>
- Hein, M. Y., Vardi, T., Shaver, E. C., Pioch, S., Boström-Einarsson, L., Ahmed, M., Grimsditch, G., & McLeod, I. M. (2021). Perspectives on the Use of Coral Reef Restoration as a Strategy to Support and Improve Reef Ecosystem Services. *Frontiers in Marine Science*, 8. <https://doi.org/10.3389/fmars.2021.618303>
- Intergovernmental Panel on Climate Change (IPCC) (Ed.). (2022). Summary for Policymakers. In *Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* (pp. 1–24). Cambridge University Press. <https://doi.org/10.1017/9781009157940.001>
- Jonas, H. D., Bingham, H. C., Bennett, N. J., Woodley, S., Zlatanova, R., Howland, E., Belle, E., Upton, J., Gottlieb, B., Kamath, V., Lessmann, J., Delli, G., Dubois, G., Ahmadi, G., Claudet, J., Cook, C., Deza, J., Grorud-Colvert, K., Gurney, G., ... Ruiz, L. (2024). Global status and emerging contribution of other effective area-based

- conservation measures (OECMs) towards the '30x30' biodiversity Target 3. *Frontiers in Conservation Science*, 5, 1447434. <https://doi.org/10.3389/fcosc.2024.1447434>
- Keith, D. A., Ghoraba, S. M. M., Kaly, E., Jones, K. R., Oosthuizen, A., Obura, D., Costa, H. M., Daniels, F., Duarte, E., Grantham, H., Gudka, M., Norman, J., Shannon, L. J., Skowno, A., & Ferrer-Paris, J. R. (2023). Contributions of Red Lists of Ecosystems to risk-based design and management of protected and conserved areas in Africa. *Conservation Biology*, n/a(n/a). <https://doi.org/10.1111/cobi.14169>
- Keith, D. A., Rodríguez, J. P., Brooks, T. M., Burgman, M. A., Barrow, E. G., Bland, L., Comer, P. J., Franklin, J., Link, J., McCarthy, M. A., Miller, R. M., Murray, N. J., Nel, J., Nicholson, E., Oliveira-Miranda, M. A., Regan, T. J., Rodríguez-Clark, K. M., Rouget, M., & Spalding, M. D. (2015). The IUCN Red List of Ecosystems: Motivations, Challenges, and Applications. *Conservation Letters*, 8(3), 214–226. <https://doi.org/10.1111/conl.12167>
- Keith, D. A., Rodríguez, J. P., Rodríguez-Clark, K. M., Nicholson, E., Aapala, K., Alonso, A., Asmussen, M., Bachman, S., Basset, A., Barrow, E. G., Benson, J. S., Bishop, M. J., Bonifacio, R., Brooks, T. M., Burgman, M. A., Comer, P., Comín, F. A., Essl, F., Faber-Langendoen, D., ... Zambrano-Martínez, S. (2013). Scientific Foundations for an IUCN Red List of Ecosystems. *PLOS ONE*, 8(5), e62111. <https://doi.org/10.1371/journal.pone.0062111>
- Knoester, E. G., Rienstra, J. J., Schürmann, Q. J. F., Wolma, A. E., Murk, A. J., & Osinga, R. (2023). Community-managed coral reef restoration in southern Kenya initiates reef recovery using various artificial reef designs. *Frontiers in Marine Science*, 10. <https://doi.org/10.3389/fmars.2023.1152106>
- Lin, B., & Cinner, J. E. (2026). Unifying bright spots research for people and nature. *Nature Ecology & Evolution*, 10(10), 1800–1811. <https://doi.org/10.1038/s41559-026-03180-5>
- Mellin, C., Brown, S., Cantin, N., Klein-Salas, E., Mouillot, D., Heron, S. F., & Fordham, D. A. (2024). Cumulative risk of future bleaching for the world's coral reefs. *Science Advances*, 10(26), eadn9660. <https://doi.org/10.1126/sciadv.adn9660>
- Mulà, C., Bradshaw, C. J. A., Cabeza, M., Manca, F., Montano, S., & Strona, G. (2025). Restoration cannot be scaled up globally to save reefs from loss and degradation. *Nature Ecology & Evolution*, 1–11. <https://doi.org/10.1038/s41559-025-02667-x>
- Nicholson, E., Andrade, A., Brooks, T. M., Driver, A., Ferrer-Paris, J. R., Grantham, H., Gudka, M., Keith, D. A., Kontula, T., Lindgaard, A., Londono-Murcia, M. C., Murray, N., Raunio, A., Rowland, J. A., Sievers, M., Skowno, A. L., Stevenson, S. L., Valderrabano, M., Vernon, C. M., ... Obura, D. (2024). Roles of the Red List of Ecosystems in the Kunming-Montreal Global Biodiversity Framework. *Nature Ecology & Evolution*, 1–8. <https://doi.org/10.1038/s41559-023-02320-5>
- NOAA NESDIS. (2026). *World's Fourth Mass Coral Bleaching Event Likely Ended in 2025*. National Environmental Satellite, Data, and Information Service. <https://www.nesdis.noaa.gov/news/worlds-fourth-mass-coral-bleaching-event-likely-ended-2025>
- Obura, D. O., Gudka, M., Samoilys, M., Osuka, K., Mbugua, J., Keith, D. A., Porter, S., Roche, R., van Hooidonk, R., Ahamada, S., Araman, A., Karisa, J., Komakoma, J., Madi, M., Ravinia, I., Razafindrainibe, H., Yahya, S., & Zivane, F. (2022). Vulnerability to collapse of coral reef ecosystems in the Western Indian Ocean. *Nature Sustainability*, 1–10. <https://doi.org/10.1038/s41893-021-00817-0>
- Robinson, J. P. W., Wilson, S. K., & Graham, N. A. J. (2019). Abiotic and biotic controls on coral recovery 16 years after mass bleaching. *Coral Reefs*, 38(6), 1255–1265. <https://doi.org/10.1007/s00338-019-01831-7>

- United Nations Environment Programme. (2026). *Limiting Overshoot: Navigating exceedance of 1.5°C and pathways towards return*. <https://doi.org/10.59117/20.500.11822/49857>
- Uribe, E. S., Luna-Acosta, A., & Etter, A. (2021). Red List of Ecosystems: Risk assessment of coral ecosystems in the Colombian Caribbean. *Ocean & Coastal Management*, 199, 105416. <https://doi.org/10.1016/j.ocecoaman.2020.105416>
- Vardi, T., Hoot, W. C., Levy, J., Shaver, E., Winters, R. S., Banaszak, A. T., Baums, I. B., Chamberland, V. F., Cook, N., Gulko, D., Hein, M. Y., Kaufman, L., Loewe, M., Lundgren, P., Lustic, C., MacGowan, P., Matz, M. V., McGonigle, M., McLeod, I., ... Montoya-Maya, P. H. (2021). *Six priorities to advance the science and practice of coral reef restoration worldwide*. <https://opus.lib.uts.edu.au/handle/10453/153979>
- Yanovski, R., & Abelson, A. (2019). Structural complexity enhancement as a potential coral-reef restoration tool. *Ecological Engineering*, 132, 87–93. <https://doi.org/10.1016/j.ecoleng.2019.04.007>
- Zawada, K. J. A., Darling, E., Jupiter, S. D., McClanahan, T. R., & Maina, J. M. (2026). *Machine-learning and prioritization models reveal climate refugia for coral reefs into 2050*. <https://ecoevorxiv.org/repository/view/11883/>
- Zeng, K., He, S., & Zhan, P. (2025). Inevitable global coral reef decline under climate change-induced thermal stresses. *Communications Earth & Environment*, 6(1), 827. <https://doi.org/10.1038/s43247-025-02790-4>