GCRMN
Global Coral Reef Monitoring Network

ICRI
International Coral Reef Initiative

Australian Government

Australian Institute of Marine Science

Status of Coral Reefs of the World: 2020

Executive Summary

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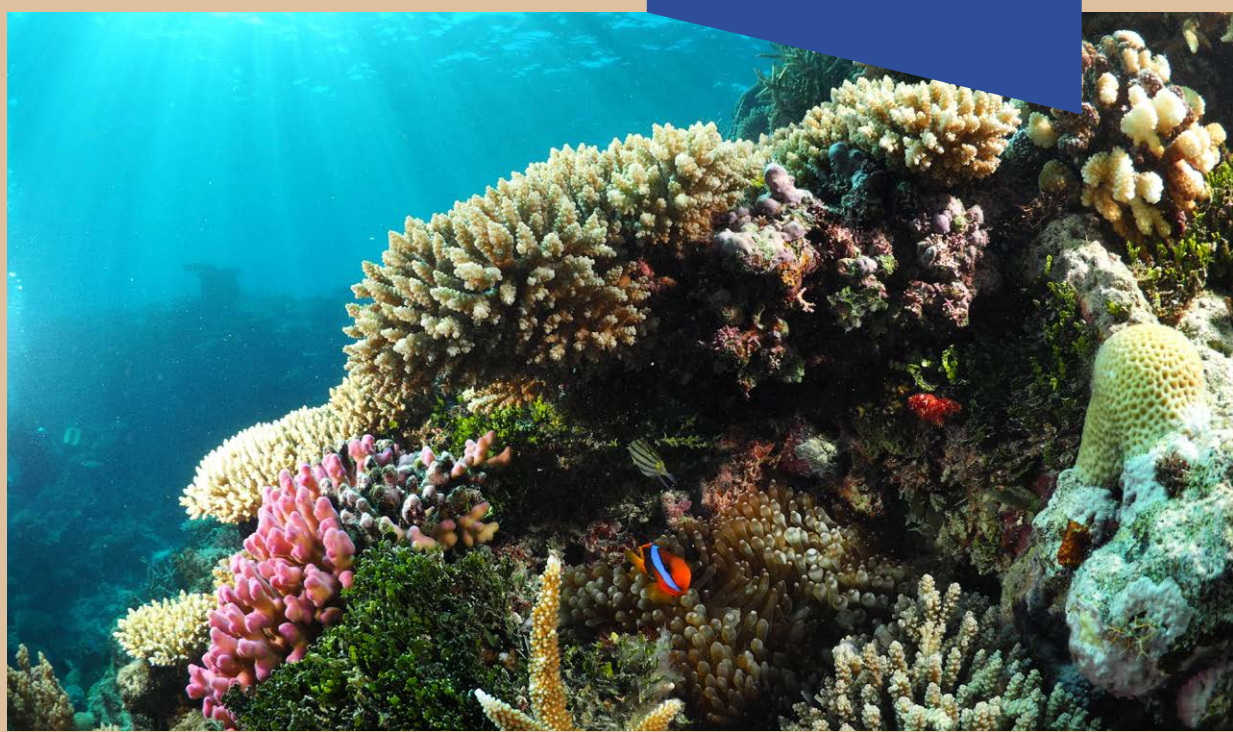

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Department of Foreign Affairs and Trade

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Executive Summary

Coral reefs occur in more than 100 countries and territories and whilst they cover only 0.2% of the seafloor, they support at least 25% of marine species and underpin the safety, coastal protection, wellbeing, food and economic security of hundreds of millions of people. The value of goods and services provided by coral reefs is estimated at US$2.7 trillion per year, including US$36 billion in coral reef tourism. However, coral reefs are among the most vulnerable ecosystems on the planet to anthropogenic pressures, including global threats from climate change and ocean acidification, and local impacts from land-based pollution such as input of nutrients and sediments from agriculture, marine pollution, and overfishing and destructive fishing practices. Maintaining the integrity and resilience of coral reef ecosystems is essential for the wellbeing of tropical coastal communities worldwide, and a critical part of the solution for achieving the Sustainable Development Goals under the 2030 Agenda for Sustainable Development.

The Global Coral Reef Monitoring Network (GCRMN) is an operational network of the International Coral Reef Initiative that aims to provide the best available scientific information on the status and trends of coral reef ecosystems for their conservation and management. The GCRMN is a global network of scientists, managers and organisations that monitor the condition of coral reefs throughout the world. The GCRMN operates through 10 regional nodes (Fig. 1).

The flagship product of the GCRMN is the *Status of Coral Reefs of the World* report that describes the status and trends of coral reefs worldwide. This sixth edition of the GCRMN *Status of Coral Reefs of the World* report is the first since 2008, and the first based on the quantitative analysis of a global dataset compiled from raw monitoring data contributed by more than 300 members of the network. The global dataset spanned more than 40 years from 1978 to 2019, and consisted of almost 2 million observations from more than 12,000 sites in 73 reef-bearing countries around the world (Fig. 1, Tab. 1)

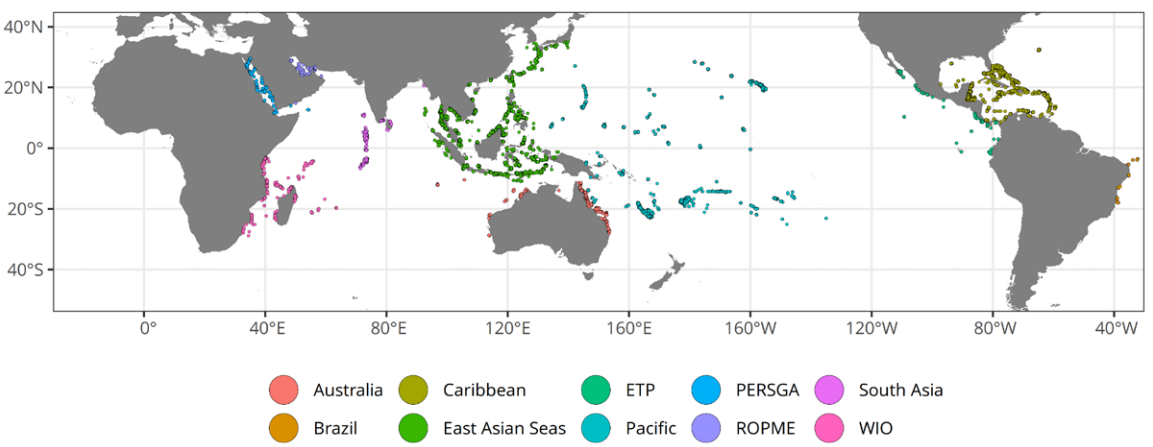

Figure 1. Distribution of monitoring sites within each of the 10 GCRMN regions from which data were compiled for the GCRMN *Status of Coral Reefs of the World: 2020* report. ETP is the Eastern Tropical Pacific. PERSGA is the area included within the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden. ROPME is the sea area surrounded by the eight Member States of the Regional Organisation for the Protection of the Marine Environment. WIO is the Western Indian Ocean.

Data contributed by scientists and organisations were collated and homogenised into a standard format that enabled statistical analysis of common variables. From the full suite of variables included within the contributed data that described benthic and fish communities, only live hard coral cover and algal cover were measured in a sufficiently consistent manner by different monitoring programs around the world to support a quantitative global analysis. Live hard coral cover is a globally accepted and universally used indicator of coral reef health, while changes in the cover of algae relative to corals is a recognized indicator of ecological change on coral reefs.

In order to estimate sub-regional, regional and global trends in the cover of live hard coral and algae, a Bayesian hierarchical modelling approach was used in which individual statistical models (fitted to biogeographical subsets of the full dataset according to Marine Ecoregions of the World[1] boundaries) were combined at progressively larger spatial scales. Because the area of coral reefs within each GCRMN region varies by two orders of magnitude, ranging from 780 km² in the Eastern Tropical Pacific to 78,272 km² in the East Asian Seas region (Tab. 1), statistical models and their spatial aggregation were weighted according to the area of coral reefs in each ecoregion, subregion and GCRMN region, based on the Tropical Coral Reefs of the World[2]. This hierarchical approach also enabled trends at a range of scales to be verified by local experts familiar with the coral reefs in those locations, and provided a credible foundation on which to build a much larger, more complex statistical model that enabled trends in hard coral and algal cover to be confidently examined and reported at multiple spatial scales. Furthermore, this approach helped reduce potential biases associated with long-term monitoring data, particularly the limited number, spatial coverage and representation of early data series; variation across programmes in site selection, methods, expertise, resources and capacity; and the remoteness and inaccessibility of many coral reef sites.

Global coral reef monitoring effort has increased substantially since 1978, with more than 91% of surveys conducted after the first mass coral bleaching event in 1998, and the majority (78%) collected between 2005 and 2018 (Fig. 2). Fewer surveys in 2019 was a consequence of applying a cut-off date at the end of 2019 for data contributions for this analysis.

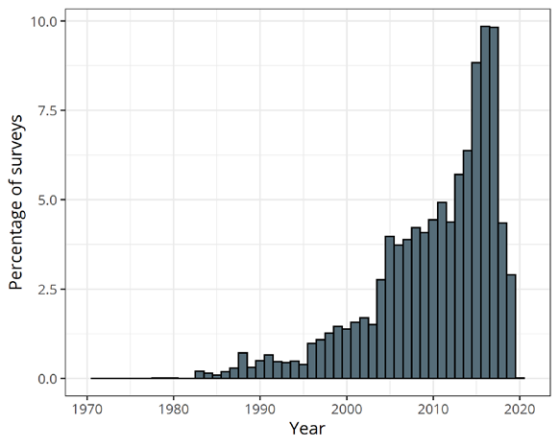

Figure 2. Histogram illustrating the proportion of the total number of surveys conducted in each year.

[1] Spalding, M. D., E. H. F., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., Halpern, B. S., Jorge, M. A., Lombana, A., Lourie, S. A., Martin, K. D., McManus, E., Molnar, J., Recchia, C. A., & Robertson, J. (2007). Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas, BioScience, Volume 57, Issue 7, Pages 573–583, https://doi.org/10.1641/B570707

[2] Institute for Marine Remote Sensing, University of South Florida (IMaRS/USF), Institut de Recherche pour le Développement (IRD), UNEP-WCMC, The WorldFish Center, and WRI, (2011). Global Coral Reefs composite dataset compiled from multiple sources for use in the Reefs at Risk Revisited project incorporating products from the Millennium Coral Reef Mapping Project prepared by IMaRS/USF and IRD . https://datasets.wri.org/dataset/tropical-coral-reefs-of-the-world-500-m-resolution-grid

Table 1. Summary statistics describing the number of countries, sites and surveys from which data were compiled for the global dataset, and the area of coral reefs in each GCRMN region. A site is a unique GPS position where data were collected. A survey is a sampling event at one site in a given year.

GCRMN Region	Number of countries contributing data/ Number of countries in the GCRMN Region with coral reefs	Reef Area		Sites		Surveys	
		Area (km²)	Proportion of global total (%)	Total Number	Proportion of global dataset (%)	Total Number	Proportion of global dataset (%)
Australia	1/1	41,802	16.10	372	3.06	3,804	10.91
Brazil	1/1	1,226	0.47	35	0.29	261	0.75
Caribbean	20/25	26,397	10.17	3,166	26.04	7,127	20.44
East Asian Seas	11/14	78,272	30.15	2,570	21.13	9,785	28.06
Eastern Tropical Pacific	6/6	780	0.30	352	2.89	1,277	3.66
Pacific	15/17	69,424	26.74	4,050	33.31	7,565	21.69
Red Sea and Gulf of Aden	6/9	13,605	5.24	243	2	574	1.65
ROPME Sea Area	7/9	2,009	0.77	68	0.56	200	0.57
South Asia	5/7	10,949	4.22	389	3.2	1,635	4.69
Western Indian Ocean	9/10	15,179	5.85	915	7.52	2,642	7.58
TOTAL	73/83*	259,647	100	12,160	100	34,870	100

*** Because some countries contribute to more that one GCRMN region (e.g Saudi Arabia contributes to both the Red Sea and Gulf of Aden and the ROPME Sea Area regions), the totals reported are not simply the sum of all countries from which data were contributed and the sum of all countries within each GCRMN region.**

At the global scale, the estimated average cover of living hard coral exhibited distinct fluctuations during the last 40 years (Fig. 3). Prior to the first mass coral bleaching event in 1998, the global average cover of hard coral was high (>30%) and stable, although the scarcity of data prior to 1998 reduced the level of certainty in estimates. The 1998 coral bleaching event killed approximately 8% of the world's coral. To put this into context, this represents more than the total amount of living coral in any one of the Caribbean, Red Sea and Gulf of Aden, South Asia or Western Indian Ocean regions. During the subsequent decade, the global average cover of hard coral recovered to pre-1998 levels (33.3% in 2009), but between 2009 and 2018, there was a progressive loss amounting to 14% of the coral from the world's coral reefs, which is more than all the coral currently living on Australia's coral reefs.

This decline was due primarily to recurring large-scale coral bleaching events. During this period, the increasing frequency and geographic extent of mass coral bleaching events have prevented coral cover from recovering. While the influences of local or regional disturbances, such as coral diseases, crown-of-thorns starfish outbreaks, tropical storms, overfishing and destructive fishing and poor water quality resulting from land-based pollution have undoubtedly played a role in the decline of coral reefs, their specific contributions were difficult to assess directly from the data without the input of local and regional experts. There is mild evidence of a small recovery in 2019, although this may be an artifact of the limited data compiled for 2018-2019.

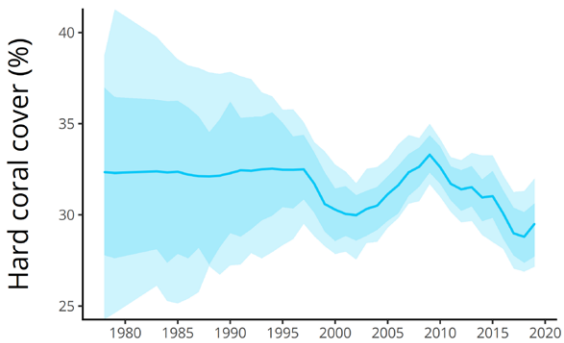

Figure 3. Estimated global average cover of hard coral (solid blue line) and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty.

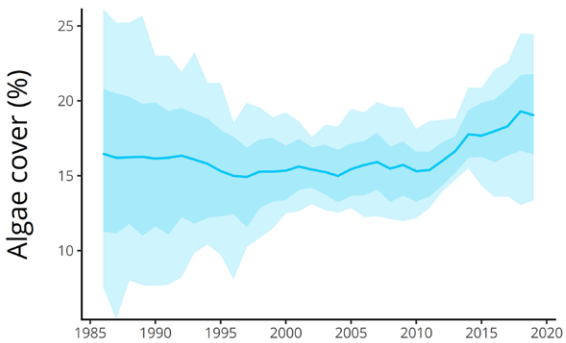

Figure 4. Estimated global average cover of algae (solid blue line) and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty.

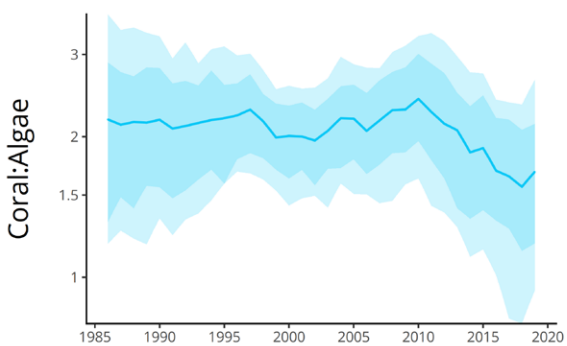

Figure 5. Estimated ratio between the global average covers of coral and algae (solid blue line) and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty.

Prior to 2011, the estimated global average cover of algae was low (~16%) and stable for 30 years (Fig. 4). Since 2011, the amount of algae on the world's coral reefs has increased by about 20%, mirroring the decrease in hard coral cover. Prior to 1998, there was, on average, more than twice as much coral on the world's reefs as algae (Fig. 5). Following the 1998 mass coral bleaching event, the cover of coral decreased but there was no complementary increase in the cover of algae, and coral cover recovered to its initial level. However, since 2011, there has been an increase in the cover of algae commensurate with the decline in coral cover. A progressive transition from coral to algae dominance in a reef community reduces the complex three-dimensional habitat that is essential to support high biodiversity and provide valuable goods and services for reef-dependent human communities.

Large-scale coral bleaching events caused by elevated sea surface temperatures (SST) are the greatest disturbance to the world's coral reefs. At a global level, strong positive global SST anomalies correspond with the major episodes of coral decline (Fig. 6), with short, sharp SST anomalies (dark red) corresponding with acute episodic declines in coral cover in 1998 and 2016, and weaker, but protracted SST anomalies (light red) corresponding with the long-term decline from 2009 to the present.

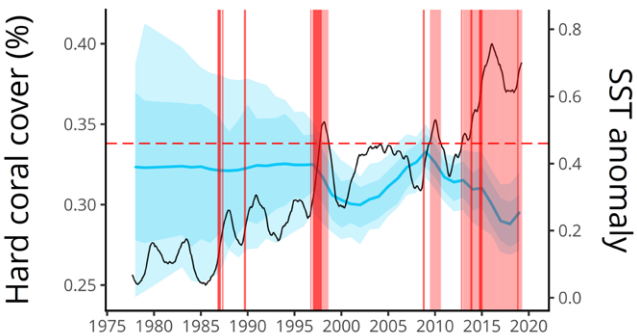

Figure 6. Estimated global average hard coral cover with the sea surface temperature (SST) anomaly from 1977 to 2020 superimposed. The blue line is the estimated global average hard coral cover with 80% (darker blue) and 95% (lighter blue) credible intervals. The black line represents the SST anomaly smoothed with an 18 month rolling mean. Periods of rapid increase in SST anomaly (darker red vertical lines) were calculated by estimating the derivatives (via numerical integration) of the smoothed SST anomaly time series. Darker red vertical red bars indicate when the rate of smoothed SST change exceeded 0.15 for two consecutive months. Lighter red vertical bars indicate when the smoothed SST anomaly exceeded 0.45 (marked by horizontal red dashed line).

Prior to 1998, regional trends in hard coral cover were broadly consistent with the global trend. The greatest impacts of the 1998 mass bleaching event were observed in the Indian Ocean, Japan and the Caribbean, with smaller impacts observed in the Red Sea, the Inner ROPME Sea Area, the northern Pacific in Hawaii and the Caroline Islands, and the southern Pacific in Samoa and New Caledonia. Subsequently, the greatest recovery was seen in those places most affected by the bleaching event, demonstrating that coral cover on some reefs was able to recover within about a decade. However, after 2010, almost all regions exhibited a decline in average hard coral cover. At the same time, most regions exhibited an increase in the cover of algae, particularly in the ROPME Sea Area, Eastern Tropical Pacific, Red Sea and Gulf of Aden, Caribbean, Australia and Brazil. The East Asian Seas and Western Indian Ocean regions were exceptions, although the cover of algae was already high in the latter.

The East Asian Seas region, which includes the Coral Triangle and contains 30% of the world's coral reefs and is the center of global hard coral diversity, showed distinctly different trends from all other GCRMN regions. This was the only region where coral cover was sustantially greater in 2019 (36.8%) than when the earliest data contributed to this analysis were collected in 1983 (32.8%) (Fig. 7A). Also, in contrast with other regions, the cover of algae progressively decreased (Fig. 7B), resulting in an average of five times more coral than algae on these reefs (Fig. 7C).

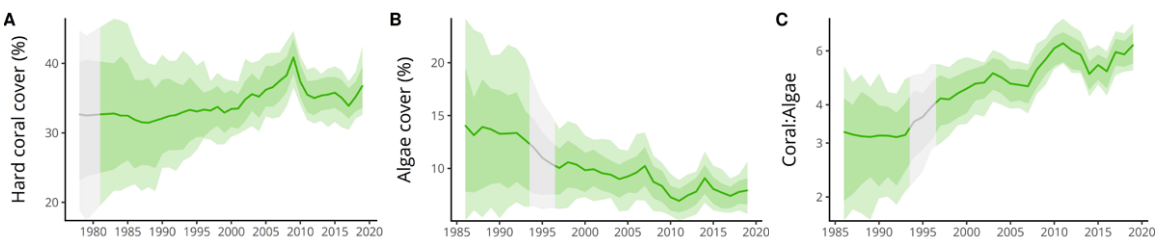

Figure 7. Estimated average cover of hard coral (A), and algae (B), and ratio of the average covers of hard coral to algae (C) for the East Asian Seas region. The solid line represents the estimated mean with 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods for which no observed data were available.

Despite SST anomalies in the East Asian Seas region being similar to those experienced in other regions, hard coral cover at the regional scale appears less affected until the last decade, when the impacts of coral bleaching events in 2010 and 2016 were evident. This suggests that the high coral cover and diversity on the coral reefs within this critically important region may have conferred a degree of natural resistance to elevated SSTs, but that more recent events were beginning to overwhelm these reefs' resistive capacity.

The key findings of this report are:

- Large scale coral bleaching events are the greatest disturbance to the world's coral reefs. The 1998 event alone killed 8% of the world's coral.
- Subsequent disturbance events, occurring between 2009 and 2018, killed 14% of the world's coral.
- There was 20% more algae on the world's coral reefs in 2019 than in 2010. Increases in the amount of algae, a globally recognised indicator of stress on coral reefs, were associated with declines in the amount of hard coral.
- Declines in global coral cover were associated with periods of either rapid increase in sea surface temperature (SST) anomaly or sustained high SST anomaly.
- Since 2010, almost all regions exhibited a decline in average coral cover. Projections of increased SSTs in the future suggest coral reefs will experience further declines in the coming decades.
- Increases in global average coral cover between 2002 and 2009, and in 2019, suggest that many of the world's coral reefs remain resilient and can recover if conditions permit.
- High coral cover and diversity may confer a degree of natural resistance to elevated SSTs. Coral reefs in the East Asian Seas region, which includes the Coral Triangle and 30% of the world's coral reefs have, on average, more coral in 2019 than they did in 1983, despite being affected by large scale coral bleaching events during the last decade.
- Reducing local pressures on coral reefs in order to maintain their resilience will be critical while global threats posed by climate change are addressed.
- Monitoring data collected in the field are essential to understand the status of, and trends in, coral reef condition. Ongoing investment in the development of methodological approaches, new technologies, capability and capacity that expands geographic coverage and enhances the quality, accessibility and interoperability of data is essential.

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