GCRMN
Global Coral Reef Monitoring Network

ICRI
International Coral Reef Initiative

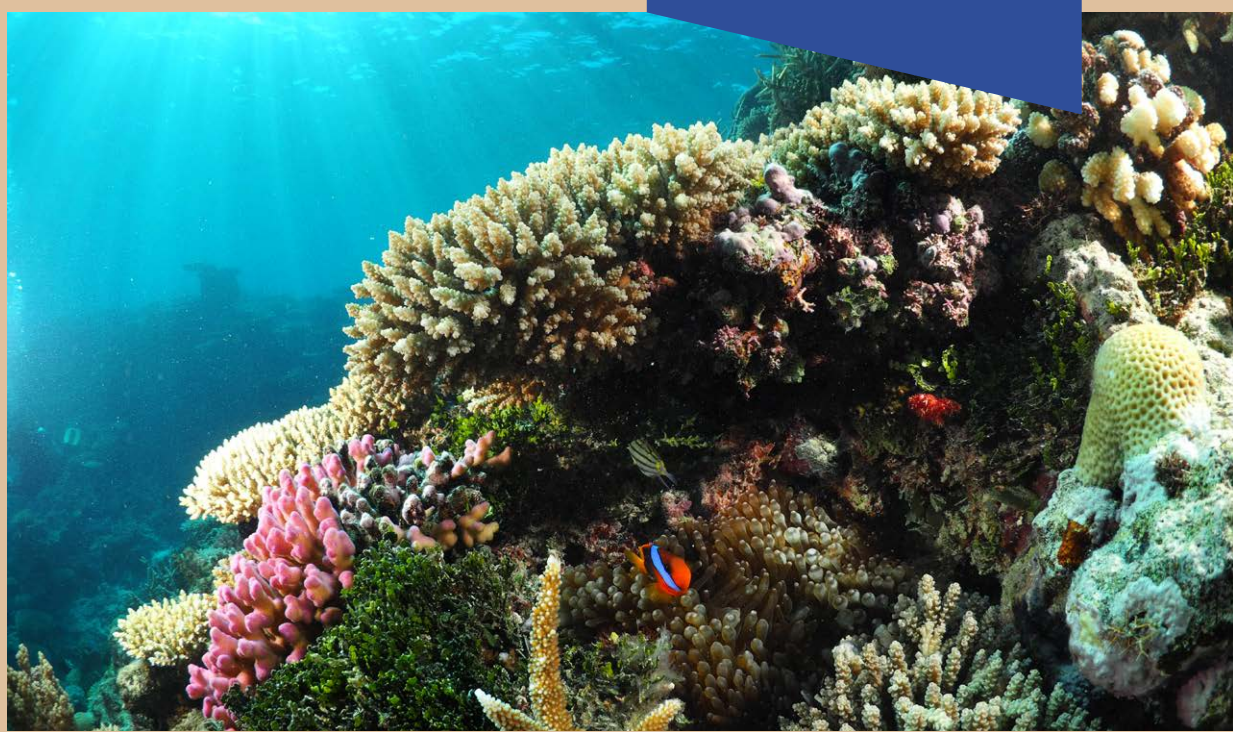
Australian Government

Australian Institute of Marine Science

# Status of Coral Reefs of the World: 2020

## Executive Summary

Edited by: David Souter, Serge Planes, Jérémy Wicquart, Murray Logan, David Obura and Francis Staub



Australian Government
Department of Foreign Affairs and Trade

Gouvernement Princier
Principauté de Monaco

Government Offices of Sweden
Ministry of the Environment and Energy

Prince Albert II of Monaco Foundation

UN environment programme 1972-2022

*The conclusions and recommendations of this report are solely the opinions of the authors, contributors and editors and do not constitute a statement of policy, decision, or position on behalf of the participating organizations, including those represented on the cover.*

# Foreword

Image: Gaetan Luci/Palais Princier

On 4th July 2018, during the ceremony marking the beginning of the co-chairmanship of Australia, Indonesia and Monaco of the International Coral Reef Initiative, I highlighted the huge responsibility of our society vis-à-vis the threats hanging over the coral reefs.

At a global scale, where they occupy less than 0.2% of the seabed, it is quite remarkable that coral reefs provide a habitat for close to 30% of all known marine species.

The socio-economic benefits they generate are clear, both in terms of food resources and attractiveness for tourists; consequently, their degradation poses a danger to the populations who depend on them.

These ecosystems represent a key indicator for ocean health. They not only suffer global impacts but also innumerable local pressures. Coastal development, overfishing and the use of destructive fishing techniques, sediments swept along by rivers containing nutrient overloads and pollutants such as pesticides, are among the main examples.

However, the greatest threat to date is warming waters brought about by human activities. Over the last decade, bleaching events have increased in frequency and intensity, preventing the corals from recovering between disturbances and resulting in a gradual decline to their status.

According to the scenarios put forward in the IPCC's special report on the ocean and cryosphere (the preparation of which was strongly advocated by Monaco), a 1.5°C increase in water temperatures in the course of this century could lead to a loss of 70% to 90% of reef areas. This loss would be almost total with a 2°C increase.

Equally, deleterious ecological changes affect ocean and coral health, such as acidification which results from the absorption of human-generated carbon dioxide emissions by the ocean, and the dramatic decline in oxygen levels linked to global warming and accelerated coastal pollution.

Faced with these observations and pessimistic outlook, the *Status of Coral Reefs of the World: 2020* report produced by the Global Coral Reef Monitoring Network (GCRMN) under the auspices of ICRI, gives us all the more reason to take action.

I would like to commend the work carried out by GCRMN's international team which resulted in a detailed analysis of global trends in the status of coral reefs, whilst underlining regional patterns. The comprehensive global dataset that underpins this report includes almost 2 million observations collected during the last 40 years from more than 12,000 sites in 73 countries.

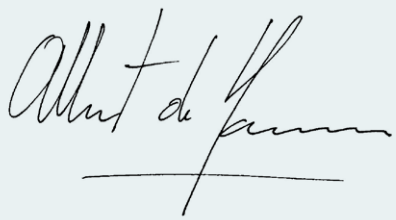
The report shows the recovery capacity of coral reefs and offers real hope regarding the effectiveness of measures to promote large-scale restoration in order to foster their recovery in the absence of major disturbances.

This report and the analyses therein are also a remarkable source of information on which current negotiations regarding the future framework for global biodiversity and 2030 goals should be based. In this respect, I call upon coral reef countries and the international community to draw on this information to pursue ambitious but realistic targets founded on Science.

As this ICRI co-chairmanship draws to a close, I am delighted to have witnessed the

strong desire for cooperation demonstrated by all the members. This report serves as an example, and I hope that this momentum will continue.

The priorities identified in this study give us further reason to take action towards reducing greenhouse gases through the development of a low-carbon economy.



**H.S.H. Albert II**
Prince of Monaco

# Foreword

Coral reefs count among the world's most precious resources. Found throughout the world's oceans, in more than 100 countries, these natural treasures, unique in their diversity and productivity, have enormous ecological, economic and cultural value. The services reefs deliver are fundamental for assuring the safety, nutrition, economic security, health and wellbeing of many millions of people.

Conserving these important global assets has been a preoccupation of the international community since the 1992 UN Conference on Environment and Development (UNCED) adopted its *Agenda 21* blueprint for sustainable development and identified coral reefs and associated ecosystems as a high priority for protection. When The International Coral Reef Initiative (ICRI) emerged in 1994, it raised the stakes, declaring in the opening statement of its 1995 *Framework for Actio*n that maintaining the condition, resources and values of coral reefs and related ecosystems was a matter of global urgency.

Despite that recognition - and the substantial effort committed since then by governments, UN agencies, research institutes, ICRI and other organisations to reef protection and management - the outlook for the world's reefs, in 2021, is bleak. The need for action to address reef degradation has moved from "high priority" to "urgent" to "critical". Reefs are at crisis point, linked to the impacts of our changing climate.

Estimates and predictions of reef loss and degradation now and in the future vary. Some scientists assess that more than a fifth of the world's coral reefs have already been lost or severely damaged. Others maintain the figure is closer to half - that over 50% of the world's coral reefs have died in the last 30 years. Some suggest that by 2070, coral reefs could be gone altogether. Predictions by the Intergovernmental Panel on Climate Change (IPCC) suggest that with global warming of 1.5 °C coral reefs would decline by 70-90% and be virtually lost with 2°C of warming. The most recent report by the IPCC shows that warming will continue at least until mid-century under all emissions scenarios and predicts that 1.5 °C and 2 °C will be exceeded this century unless deep reductions in greenhouse gas emissions occur in coming decades.

Since they first appeared more than 400 million years ago, coral reefs have faced and survived many threats. We know they have a capacity for recovery, but the time frames for those previous recoveries were long, often measured in millennia. Now the stresses and changes from human activities are happening faster than their ability to adapt. The window for action is closing. In July 2021, scientists at the International Coral Reef Symposium said the coming decade will likely offer the last chance for policy makers at all levels to prevent coral reefs from heading towards worldwide collapse. If coral reefs disappear, other marine realms will follow.

For those policy makers, and everyone involved with reef management, the need to have the most up to date and comprehensive information on the condition of the world's coral and coral reefs is fundamental: and that is exactly what this report provides. After a hiatus of 13 years, the Global Coral Reef Monitoring Network, established

in 1995 to support the ICRI Framework for Action, has delivered the first global statement on the condition of coral reefs since 2008. Importantly, it is in a new quantitative format, the first to be based on a quantitative analysis of a global dataset that contains almost 2 million observations collected by more than 300 scientists from more than 12,000 sites in 73 coral-reef bearing nations.

Production of the report in its new form was a monumental task, which benefited from the commitment and generous support of the ICRI Secretariat, hosted by Australia, Monaco and Indonesia, the Australian Government, through the Department of Foreign Affairs and Trade and the Australian Institute of Marine Science, which hosts the GCRMN, the Principality of Monaco, the Government of Sweden, the UN Environment Program, the Prince Albert II of Monaco Foundation, CRIOBE, CORDIO and NOAA.

The timing of the Report's release, marking the hand-over of the ICRI Secretariat to the USA, is especially fortuitous. With parties to the Convention on Biological Diversity soon to consider a new post-2020 global biodiversity framework to guide actions to preserve and protect nature and its essential services to people over the coming decade; and the world's governments convening at the UN Climate Change Conference in Glasgow later this year, the report provides timely input regarding the condition of one of Earth's most vulnerable ecosystems to climate change.

As someone involved with the inception of ICRI and the GCRMN, still deeply engaged with efforts to protect coral reefs, I welcome warmly the decision to reinvigorate the GCRMN and the return of this important global report on the status of the world's coral reefs. I congratulate everyone involved with its production, including data contributors, authors, editors, regional coordinators, the working group established to reinvigorate the GCRMN and the GCRMN Steering Committee. I have every confidence it will become an essential reference for managers and decision-makers, and make a strong contribution to global, regional and national efforts to address the critical challenges facing the world's coral reefs.

**The Honourable Penelope Wensley AC**

***Chairman***
Australian Institute of Marine Science Council

***Chairman***
Great Barrier Reef 2050 Plan Advisory Committee

# Foreword

*The ICRI Secretariat Co-chairs*

Coral reefs are critically important ecosystems that underpin ocean sustainability and the economic, social and cultural security of hundreds of millions of people around the world. Despite their immense value, they are uniquely vulnerable to the increasing global threat of climate change, as well as other anthropogenic impacts.

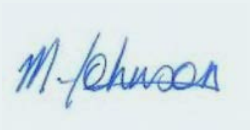
Over 25 years ago, the International Coral Reef Initiative (ICRI) was started by eight countries, all focussed on protecting and managing our coral reef resources. ICRI established the Global Coral Reef Monitoring Network (GCRMN) in 1995 to report on the condition of the world's coral reefs, recognising the need for accurate and comprehensive information on the state of reefs.

In 2018 at the first ICRI General Meeting under the Australia-Indonesia-Monaco Secretariat, ICRI members agreed to strengthen and reinvigorate the GCRMN under the ICRI Secretariat Plan of Action. A major outcome of this has been the development of this report, which could not have been realised without tremendous effort and cooperation among ICRI members and the GCRMN regions along with the leadership of the Australian Institute of Marine Science.

The report is pivotal as it allows us to understand the condition and trend of the global coral reef estate. As the report reveals, we have already witnessed large-scale losses of coral from the world's coral reefs over the last 40 years. It is increasingly evident that to prevent further declines in coral reefs we must take bold and collective action to reduce pressures and build reef resilience.

In this context, we recall the important role that science has to play in ensuring our actions to protect and restore coral reefs are informed by accurate and evidence-based information. Science underpins effective management and can be used to galvanise action at local, regional and global scales. The GCRMN will continue to build regional capability to collect data and provide the most accurate picture to inform these efforts.

While the results of the report are sobering, there are examples of the ability of coral reefs to recover in the absence of major disturbances. This reinforces our conviction that we need to step up and accelerate efforts at all levels to address key threats and increase global action at all levels to reduce the extent of climate change impacts. If we act together, we can make a difference to secure the future of coral reefs for generations to come.



**Margaret Johnson**

*General Manager*
Great Barrier Reef Marine Park Authority, ICRI Co-chair for Australia

**Dr. Pamuji Lestari**

*Acting Director General of Marine Spatial Management*
Ministry of Marine Affairs and Fisheries, Indonesia, ICRI Focal Point for Indonesia

# Acknowledgements

This sixth GCRMN *Status of Coral Reefs of the World: 2020* report is the result of more than three-years of effort, supported by an extensive network of partners, contributors and scientists whose commitment to the monitoring and conservation of coral reefs is gratefully acknowledged.

The production of this milestone report was only possible through the voluntary contributions of almost 2 million observations from more than 300 contributors, from 73 reef-bearing countries. We specifically thank all the contributors and organizations, who are named throughout this report, for their generous contributions of data, information and time including the analysis of data, production of regional chapters and knowledge boxes throughout, recognizing the assistance in the editing and proof reading, especially the reviewing of regional chapters, often at very short notice: Alexander A. Venn; Alfred DeGemmis; Andreas Andersson; Caren Eckrich; David Crossman; David Mead; Derek Manzello; Emily Darling; Gabriel Grimsditch; Haley Williams; Ian McLeod; Jacqueline De La Cour; Jennifer Koss; Joannie Jomitol; Kim Fisher; Lina Mtwana Nordlund; Lorenzo Alvarez; Manuel Gonzalez-Rivero; Margaret Miller; Mathew Wyatt; Mishal Gudka; Rosa Rodríguez; Sylvie Tambutté; Tali Vardi; Tom Moore; Ulrike Kloiber; Greg Asner; Paulina Gerstner; Kirk Larsen; Laetitia Hédouin, Gonzalo Pérez-Rosales Blanch, Michel Pichon and Héloïse Rouzé.

We would like to acknowledge the GCRMN Regional Coordinators whose dedication to the collection and collation of valuable coral reef monitoring data throughout the GCRMN regional nodes enabled this report: Australia: David Souter, Murray Logan; Brazil: Beatrice Padovani Ferreira; Caribbean: Erica Towle, Mark Vermeij, Sandrine Pivard; Eastern Tropical Pacific: Franz Smith, Héctor Reyes Bonilla; Pacific: Serge Planes; PERSGA: Maher Amer; ROPME: John Burt; South Asia: Nishan Perera; East Asia: Tadashi Kimura, Karenne Tun; WIO: David Obura, Mishal Gudka.

The members of the GCRMN Policy and Communications Task Force are also kindly thanked for their support throughout the dissemination of this report; Lisa Rolls (UNEP), Chuck Cooper (Vulcan), Teki Akuetteh (Vulcan), Janet Greenlee (Vulcan) and Thomas Dallison (ICRI Secretariat).

A special thank you is also extended to Sharon Barnwell (AIMS) and Thomas Dallison (ICRI Secretariat) for their assistance in the production of this report and the coordination of workshops and launch and dissemination events.

In addition to many of those already mentioned, we would also like to thank all those who participated in, and were involved in the organization and administration, the seven GCRMN hosted workshops during 2019 and 2020:

| | | |
|---|---|---|
| May 2019 | GCRMN Global technical workshop | Thailand |
| June 2019 | Workshop on regional data analysis of coral monitoring in the East Asia region | Malaysia |
| September 2019 | Workshop on regional data analysis of coral reef monitoring in the Red Sea region | Egypt |
| November 2019 | Workshop on regional data analysis of coral reef monitoring in the Regional Organization for the Protection of the Marine Environment (ROMPE) Sea Area (West Asia) | Oman |
| January 2020 | Workshop on regional data analysis of coral reef monitoring in the South Asia Sea region | Maldives |
| January 2020 | Regional Workshop on regional data analysis of coral reef monitoring for the Wider Caribbean | Bonaire |
| February 2020 | Data validation workshop | Thailand |

*Main programs, organizations and affiliations of data contributors to the GCRMN 2020 report*

## 1. Universities, research programs and national initiatives

- Institute of Marine sciences (IMS) of the University of Dar es Salaam, Tanzania
- Kenya Marine and Fisheries Research Institute, Kenya
- Kenya Wildlife Service, Kenya
- State University of Zanzibar (SUZA), Zanzibar, Tanzania
- Tanga Coelacanth Marine Park, Tanzania
- UniLúrio, Mozambique
- Marine Parks and Reserves Unit (MPRU), Tanzania
- Marine Parks and Reserves Authority (MPRA), Tanzania
- Australian Institute of Marine Science (AIMS), Australia
- Atlantic and Gulf Rapid Reef Assessment (AGRRA)
- Brazilian Chico Mendes Institute of Biodiversity (ICMBIO)
- Centre national de la recherche scientifique (CNRS)
- École Pratique des Hautes Études (EPHE)
- Institut national des sciences de l'Univers (INSU)
- Infrastructure de recherche littorale et côtière (IR-Ilico)
- Service National d'Observation Corail (SNO Corail, CRIOBE)
- Réseau d'Observation des Récifs coralliens (RORC)
- XL Catlin Seaview Survey
- Department of Biodiversity, Conservation and Attractions (DBCA), Australia
- Institut de Recherche pour le développement (IRD), France
- Initiative Française pour les Récifs Coralliens (IFRECOR), France
- Instituto de Investigaciones Marinas y Costeras (INVEMAR), Colombia
- Université de la Réunion, France
- Université des Antilles, France
- Université de la Nouvelle-Calédonie, France
- Université de Perpignan Via Domitia (UPVD), France
- University of Hawai□i, United-States
- Réserve Naturelle Marine de La Réunion (RNMR), France
- Institut des Récifs Coralliens du Pacifique (IRCP)
- Terres Australes et Antarctiques Françaises (TAAF), France
- Réserve naturelle de Saint-Martin, France
- University of Warwick, United-Kingdom
- Nova Southeastern University (NSU), United-States
- University of Genoa (UNIGE), Italy
- Universidad Nacional Autónoma de México (UNAM) Facultad de Ciencias, Mexico
- Centro de Investigación y de Estudios Avanzados (CINVESTAV), Mexico
- Universidad Veracruzana, Mexico
- National Parks Board, Singapore
- University of Maine System (UMS), United-States
- National University of Singapore (NUS), Singapore
- Federal University of Pernambuco, Recife (UFPE), Brazil
- Lancaster University, United Kingdom

- National Oceanic and Atmospheric Administration (NOAA), United-States
- NOAA Coral Reef Conservation Program (CRC) - National Coral Reef Monitoring Program, United States
- Smithsonian Institution, United-States
- California State University Northridge (CSUN), United-States
- Universidad Nacional de Colombia (UNAL), Colombia
- Ministry of Marine Resources, Cook Islands
- Saba Bank National Park, Netherlands
- Centro de Investigaciones Marinas, Universidad de la Habana (UH), Cuba
- Japan Wildlife Research Center (JWRC), Japan
- James Cook University (JCU), Australia
- National Park Service (NPS), United-States
- National Environment and Planning Agency (NEPA), Jamaica
- University of the West Indies (UWI), Jamaica
- University of Rhode Island (URI), United-States
- Sultan Qaboos University (SQU), Sultanate of Oman
- Caribbean Netherlands Science Institute (CNSI), Netherlands
- Palau International Coral Reef Center (PICRC), Republic of Palau
- University of British Columbia (UBC), Canada
- Service de l'Environnement, Wallis et Futuna
- Maldives Marine Research Centre (MRC), Maldives
- University of Queensland (UQ), Australia
- Commonwealth of the Northern Mariana Islands (CNMI), Division of Coastal Resources
- King Abdullah University of Science and Technology (KAUST), Saudi Arabia
- Southeast Coral Reef Evaluation and Monitoring Project (SECREMP), United-States
- Coral Reef Evaluation and Monitoring Project (CREMP), United-States
- Oceanographic Research Institute (ORI), South-Africa
- Seaflower Research and Conservation Foundation
- Caribbean Research and Management of Biodiversity (CARMABI)
- Universidad Simón Bolívar - Centro de Biodiversidad Marina, Venezuela
- Universidad Nacional Aútonoma de México (UNAM), Mexico
- Florida Fish & Wildlife Conservation Commission (FWC)
- Centre for Resource Management and Environmental Studies (CERMES), Barbados
- Bermuda Reef Ecosystem Analysis and Monitoring Programme (BREAM)
- Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Costa Rica
- New York University - Abu Dhabi (NYU), United Arab Emirates
- Islamic Azad University, Iran
- Hawaii Institute of Marine Biology, United-States
- Qatar University, Qatar
- The Royal Marine Conservation Society of Jordan (JREDS), Jordan
- Suganthi Devadason Marine Research Institute (SDMRI), India
- Ocean University of Sri Lanka (OCUSL), Sri Lanka
- Marine Biology Regional Centre (MBRC) Zoological Survey of India
- Chinese University of Hong Kong
- Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA)
- Biodiversity Research Center, Academia Sinica, Taiwan

- South China Sea Institute of Oceanology, Chinese Academy of Sciences, China
- Korean Institute of Ocean Science and Technology (KIOST), South Korea
- Department of Fisheries Conservation, Fisheries Administration, Ministry of Agriculture, Forestry and Fisheries, Cambodia
- Indonesian Institute of Science (LIPI), Indonesia
- Ministry for Marine Conservation and Biodiversity, Indonesia
- University of Malaya (UM), Malaysia
- University of Malaysia Sabah (UMS), Malaysia
- University of the Philippines (UP)
- Ramkhamhaeng University (RU), Thailand
- Institute for Marine Research (IMR), Philippines
- Institute of Oceanography, Vietnam

## 2. NGO and other organizations

- Biosphere Foundation
- Coral Cay Conservation (CCC)
- Arocha Kenya
- BECOMING Project 2016
- Chumbe Island Coral Park (CHICOP)
- Comoros Coral Reef Monitoring Network (CRMN)
- Coastal Oceans Research and Development in the Indian Ocean (CORDIO East Africa)
- Islands Conservation Society
- Reef Conservation
- Seychelles Islands Foundation (SIF)
- AIDE Comoros
- Green Island Foundation Seychelles (GIF)
- PRISM, Madagascar
- Healthy Reef Initiative (HRI)
- The Nature Conservancy (TNC)
- World Wildlife Foundation (WWF)
- Wildlife Conservation Society (WCS)
- Khaled bin Sultan Living Oceans Foundation
- Reef Check
- Fauna and Flora International (FFI)
- Blue Resources Trust (BRT), Sri Lanka
- Banyan Tree Global Foundation
- Nature Foundation
- Nature Seychelles
- Blue Ventures
- Dahari
- Marine Conservation Society Seychelles (MCSS)
- Madagascar Research and Conservation Institute (MRCI)
- Operation Wallacea (Opwall)
- Project Azraq
- Stichting Nationale Parken Bonaire (STINAPA) Bonaire
- 5OES

- Reef Conservation
- Instituto Recifes Costeiros
- Coral Triangle Center
- The Reef-World Foundation
- Nova Blue Environment

The GCRMN Steering Committee listed below provided substantial assistance, advice and support - we thank them all. The host of the GCRMN, the Australian Institute of Marine Science is specifically thanked.

### *Membership of the GCRMN Steering Committee is comprised of:*

- ICRI Host Secretariat representatives (chair)
  - Australia
  - Indonesia
  - Monaco
- UN Environment
- Non-government/technical ICRI members
  - WWF International
  - UNESCO-IOC
- Major supporters of the GCRMN
  - USA/NOAA
  - France/CRIOBE
  - Seychelles
  - UK/JNCC
- Global Coordinator
  - Australian Institute of Marine Science
- Representatives of Regional Networks
  - Western Indian Ocean
  - Pacific
  - East Asia Region
  - Eastern Tropical Pacific
- Invited members such as leads of current Task Forces
- Host institution
  - Australian Institute of Marine Science

A new Implementation and Governance Plan for the GCRMN has been drawn up, utilising recommendations from a GCRMN meeting held in Townsville, Australia, on 23rd May 2017, and built up through extensive consultations through 2018 with ICRI and GCRMN members. Two GCRMN working group meetings (April 2018 and September 2018) focused on ensuring the Implementation and Governance Plan will meet the needs of GCRMN participants and ICRI members, and the final plan was adopted during the 33rd rd General Meeting of ICRI, December 2018 in Monaco. We would like to thank all the members of this working group: Francis Staub, ICRI and Jerker Tamelander, UN Environment (working group convenors); Dr. David Obura, CORDIO East Africa (lead author), Amanda Brigdale (Great Barrier Reef Marine Park Authority (GBRMPA) and Department of Foreign Affairs and Trade (DFAT), Australia), Chuck Cooper (Vulcan Inc. USA), Wilfrid Deri (Ministry of State, Monaco), Hadi Yoga Dewanto (Ministry of Marine Affairs and Fisheries, Republic of Indonesia), Helen Fox (Vulcan Inc. USA),

Akiko Hamada-Ano (South Pacific Regional Environment Programme (SPREP)), Jane Hawkridge (Joint Nature Conservation Commission (JNCC, UK) ), Kirsten Isensee (Intergovernmental Oceanographic Commission of UNESCO - Ocean Science Section), Margaret Johnson (GBRMPA, Australia), Justine Kimball (NOAA Coral Reef Conservation Program (CRCP), USA), Tadashi Kimura (Japan Wildlife Research Center (JWRC)), Lucie Labbouz (Regional Activity Centre for Specially Protected Areas and Wildlife (SPAW-RAC) ), Ben Palmer (GBRMPA, Australia), Jason Philibotte (NOAA CRCP, USA), Serge Planes (Centre de Recherche Insulaire et Observatoire de l'Environnement (CRIOBE, France), Heidi Prislan (Department of Foreign Affairs and Trade, Australia), Manuel Gonzales Rivero (Australian Institute of Marine Science (AIMS)), Franz Paul Smith (Charles Darwin Foundation, Ecuador), David Souter (AIMS), Aurélie Thomassin (Ministry for Ecological and Solidary Transition, France), Karenne Tun (National Parks Board, Singapore).

We are grateful for the encouragement and financial support provided by The Government Offices of Sweden - Ministry of the Environment and Energy; Gouvernment Princier Principauté de Monaco; Fondation Prince Albert II de Monaco; Australian Government through the Department of Foreign Affairs and Trade and Australian Institute of Marine Science; United Nations Environment Programme; and Vulcan Inc.

Furthermore, we would like to give our acknowledgments to the Great Barrier Reef Marine Park Authority, the Government of Indonesia, and the Principality of Monaco, as co-chairs of the International Coral Reef Initiative (ICRI) Secretariat for their consistent support of the GCRMN.

# 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)

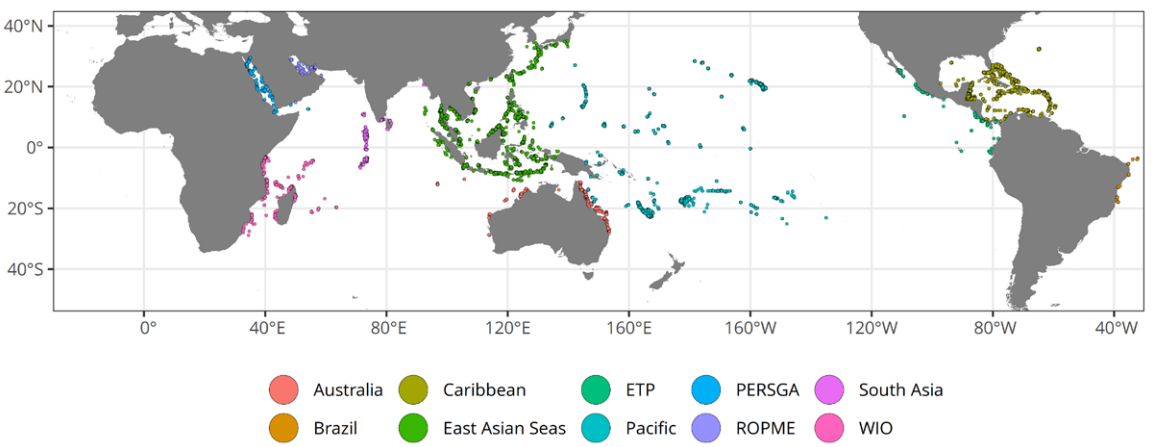



**Figure 1.** Distribution of monitoring sites within each of the 10 GCRMN regions from which data were compiled for the GCRMN *Status of Coral Reefs of the World: 2020* report. ETP is the Eastern Tropical Pacific. PERSGA is the area included within the Regional Organization for the Conservation of the 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 subregional, 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.

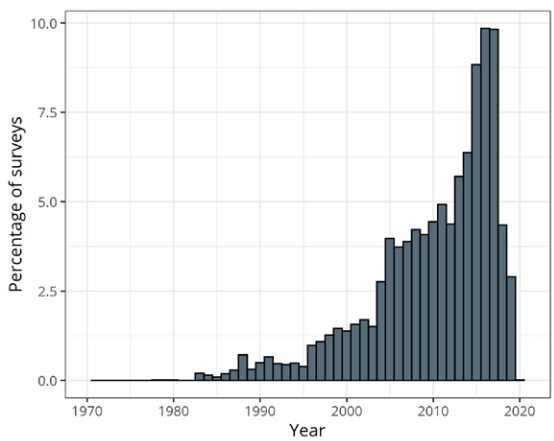



**Figure 2. Histogram illustrating the proportion of the total number of surveys conducted in each year.**

[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.

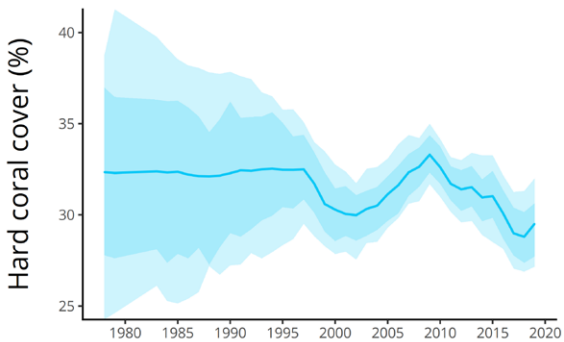



**Figure 3.** Estimated global average cover of hard coral (solid blue line) and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty.

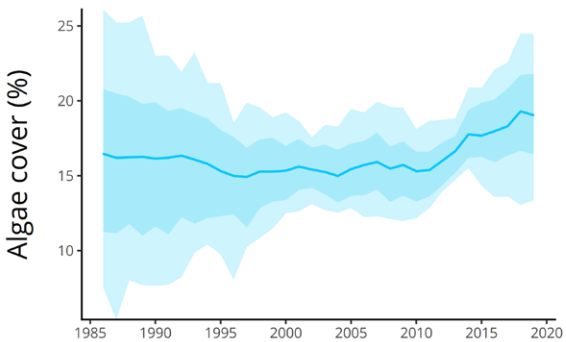



**Figure 4.** Estimated global average cover of algae (solid blue line) and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty.

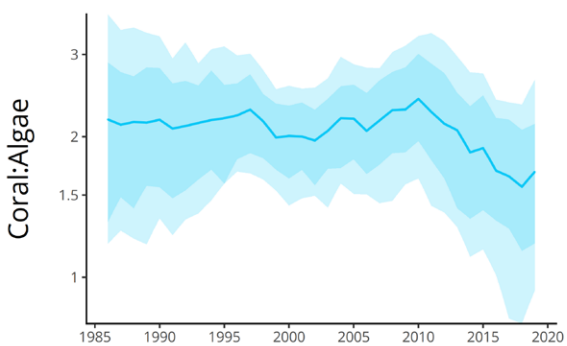



**Figure 5.** Estimated ratio between the global average covers of coral and algae (solid blue line) and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty.

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.

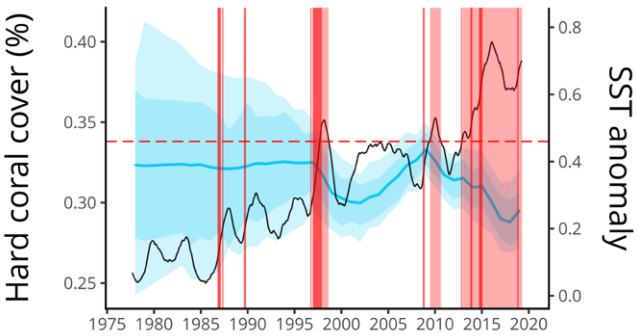



**Figure 6.** Estimated global average hard coral cover with the sea surface temperature (SST) anomaly from 1977 to 2020 superimposed. The blue line is the estimated global average hard coral cover with 80% (darker blue) and 95% (lighter blue) credible intervals. The black line represents the SST anomaly 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).

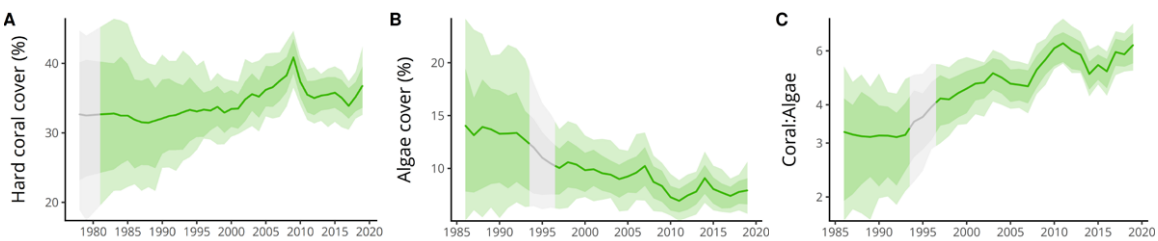



**Figure 7.** Estimated average cover of hard coral (A), and algae (B), and ratio of the average covers of hard coral to algae (C) for the East Asian Seas region. The solid line represents the estimated mean with 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of 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.

CORDIO

CRIOBE
USR3278
Centre de Recherches Insulaires et Observatoire de l'Environnement