Status of Coral Reefs of the World: 2020

Chapter 5. Status and trends of coral reefs of the Western Indian Ocean region

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

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Chapter 5.

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Authors: David Obura, Mishal Gudka, Sean Porter, Rose Abae, Pierre-André Adam, Aly Bachiry Adouhouri, Céline Agathe-Miternique, Said Ahamada, Mmadi Ahamada, Soifa Ahmed, Nassir Amiyo, Paul Anstey, Kike Ballesteros, Jim Beets, Charlotte Berkström,, Hawthorne Beyer, Lionel Bigot, Chico Birrell, Emeline Bouvelle, Eric Brown, Christophe Cadet, Nicole Caudana, Bruce Cauvin, Pascale Chabanet, Julie Church, Jérôme Clotagatide, Isabel Marques da Silva, Juliette Damien, Emily Darling, Solomon Davida, Marine Dedeken, Willy Domitin, Sirilo Dulunaqio, Patrick Durville, Linda Eggertsen, Eylem Elma, Ben Fleay, Margaret Fox, Sarah Freed, Jan Freiwald, Alan Friedlander, Albert Gamoe, Rémi Garnier, Paul Giannasi, Whitney Goodell, Charlotte Gough, Nick Graham, Alison Green, Gabriel Grimsditch, Imogen Hamer, Arielle Inès Hoamby, Ove Hoegh-Guldberg, Colin Jackson, Stacy Jupiter, Hassan Kalombo, Juliet Karisa, Siriya Karissa, Jillo Katello, Joseph Kilonzo, Ulrike Kloiber, John David Komakoma, Roberto Jean-Luc Komeno, Abigail Leadbeater, Clément Lelabousse, Mariliana Leotta, Tom Leven, Jean Maharavo, Jairos Mahenge, Louise Malaise, Marine Malen-Francoise, Sangeeta Mangubhai, Zamil Mannfou, Lola Massé, Phanor Montoya Maya, Adfaon Mchinda, Nassur Ahamada Mdroimana, Modesta Medard, Mouchtadi Mmadi, Fiona Moejes, Misbahou Mohamed, Mohammed S. Mohammed, Djaffar Mouhidine, Rachad Mourid, Peter Musembi, Josephine Mutiso, Edward Mwamuye, Jelvas Mwaura, Odile Naim, Yashika Nand, January Ndagala, Jean-Benoit Nicet, Judith Nyunja, Pádraig O'Grady, Bernard Ogwoka, Jennifer Olbers, Mike Olendo, Lorna Parry, Marcos A.M. Pereira, Karine Pothin, Fouad Abdou Rabi, Volanirina Ramahery, Ravaka Ranaivoson, Manuel Gonzalez Rivero, David Rowat, Tévamie Rungassamy, Faissoil Ahmed Said, Michael H. Schleyer, Naomi Scholten, Chloe Shute, Erwan Sola, Emmanuel Tessier, Ali Makame Ussi, Maunoa Vesarikaro, Effy Vessaz, Jeanne Wagner, Andra Whiteside, Julien Wickel, Shaun Wilson, Jacques van Wyk, Saleh A.S. Yahya.

1. Geographic information and context

Key numbers:

- Total area of coral reefs: 15,180 km^2
- Proportion of the world's coral reefs: 5.85%
- Number of countries with coral reefs: 10
- Number of Marine Ecoregions of the World (MEOW) ecoregions: 10

The Western Indian Ocean (WIO) region comprises almost 6% (about 15,180 km^2) of the total global area of coral reefs, and the region is a globally important hotspot for coral reef biodiversity. The WIO includes sovereign states along the eastern and southern African mainland (Somalia, Kenya, Tanzania, Mozambique, South Africa), island states (Mauritius, Madagascar, Comoros, Seychelles), as well as overseas territories (Reunion, France). The human population has grown considerably during the last century, with the states named now supporting ca. 220 million people, of which some 69 million live within 100 km of the coastline. Coral reef ecosystems underpin the economies of the countries in the region, particularly through the fisheries and tourism sectors, and provide livelihood opportunities and income for local communities estimated at US$ 8.4 billion annually. WIO coral reefs are estimated to have an asset value of U$ 18.1 billion[1].

The GCRMN WIO region is a distinct biogeographic province comprised of 10 marine ecoregions[2], which have been combined into five subregions for this analysis (Tab. 5.1, Fig. 5.1).

Table 5.1. The subregions comprising the Western Indian Ocean region, the area of reef they support, and the constituent Marine Ecoregions of the World (MEOW)[2].

Subregion	Reef Area (km^2)*	Proportion of Reef Area within the WIO Region (%)	Constituent Marine Ecoregions of the World
1	6,441	42.43	93: Central Somali Coast 94: Northern Monsoon Current Coast 95: East African Coral Coast
2	1,935	12.75	96: Seychelles
3	1,076	7.09	97: Cargados Carajos/Tromelin Island 98: Mascarene Islands
4	5,442	35.85	99: Southeast Madagascar 100: Western and Northern Madagascar
5	285	1.88	101: Bight of Sofala/Swamp Coast 102: Delagoa

*World Resources Institute. Tropical Coral Reefs of the World (500-m resolution grid), 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

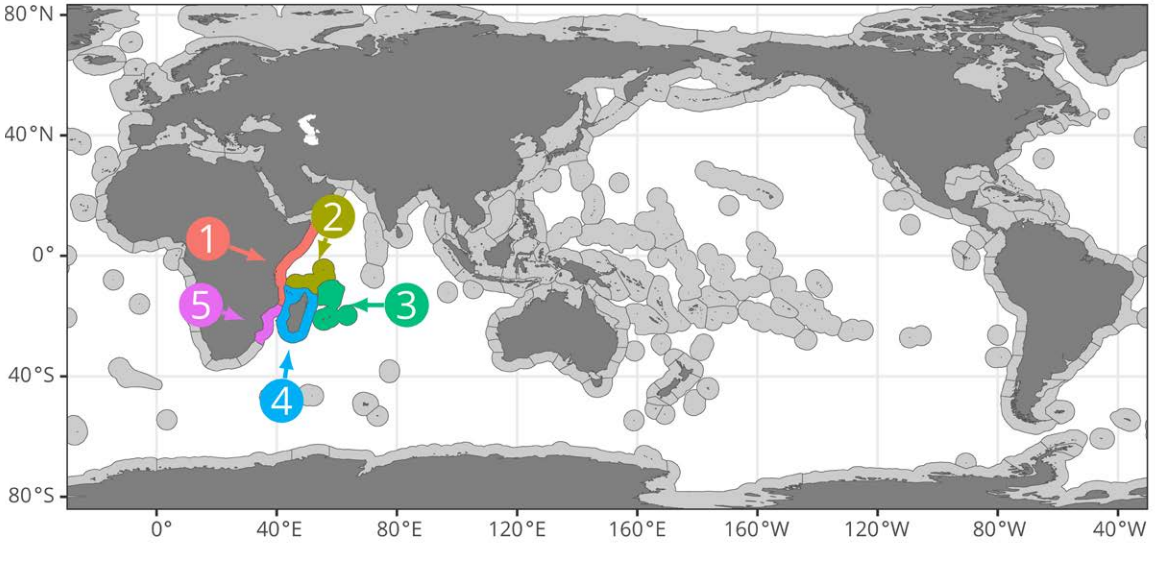

Figure 5.1. Map of each subregion comprising the Western Indian Ocean region. The number ascribed to each subregion corresponds with that in Table 5.1.

1 Obura D, Gudka M, Rabi FA, et al (2017) Coral reef status report for the Western Indian Ocean. Global Coral Reef Monitoring Network (GCRMN)/International Coral Reef Initiative (ICRI)

2 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. Summary of data contributed to this report

Key numbers:

- Number of countries from which monitoring data were used: 9 (of 10)
- Number of sites: 915
- Number of observations: 25,570
- Longest time series: 26 years

General features:

Monitoring sites were spread across all five subregions, with a greater number of sites in Kenya, Tanzania and the Mascarene Islands (Tab. 5.2). Over half of all sites were surveyed in one-off assessments, while 6% of sites had been surveyed over periods exceeding 15 years (Fig. 5.2, Fig. 5.3A). The number of long-term monitoring sites was similar in subregions 1, 2, 3 and 4, but only one long term monitoring site occurred in subregion 5 (Tab. 5.2). The data contributed to this analysis spanned approximately 30 years, with the earliest data being collected in 1985 (Fig. 5.3B). Relatively few surveys were collected during the 1980s and 1990s, but a sharp increase in the number of surveys occurred in 1998-99 in response to the first global mass coral bleaching event, with this level of monitoring effort persisting until now (Fig. 5.3B). Line-intercept transects were the most frequently used survey method (27%), although point-intercept transects (21%) and photo-quadrats (7%) were also commonly used (Fig. 5.4). Unfortunately, the method used to conduct a large proportion (44%) of surveys was not described (Fig. 5.4). Data contributed for the WIO region and incorporated into the global dataset were provided at a summary level for each site, and additional data sources included from publications. Full details are reported in Obura et al. (2017).

Table 5.2. Summary statistics describing data contributed from the Western Indian Ocean region. An observation is a single record within the global dataset (i.e. one row). A site is a unique GPS position where data were recorded. A site was considered a long-term monitoring site if the time between the first survey and the most recent survey was greater than 15 years. Such sites may have been surveyed multiple times during the intervening period.

Western Indian Ocean subregions	Observations		Sites		Long term monitoring sites	
	Total Number	Proportion of global dataset	Total Number	Proportion of global dataset	Total Number	Proportion of global dataset
All	25,570	2.64	915	7.52	64	10.88
1	5,893	0.61	378	3.11	16	2.72
2	882	0.09	172	1.41	21	3.57
3	3,330	0.34	39	0.32	14	2.38
4	13,790	1.42	243	2	12	2.04
5	1,675	0.17	83	0.68	1	0.17

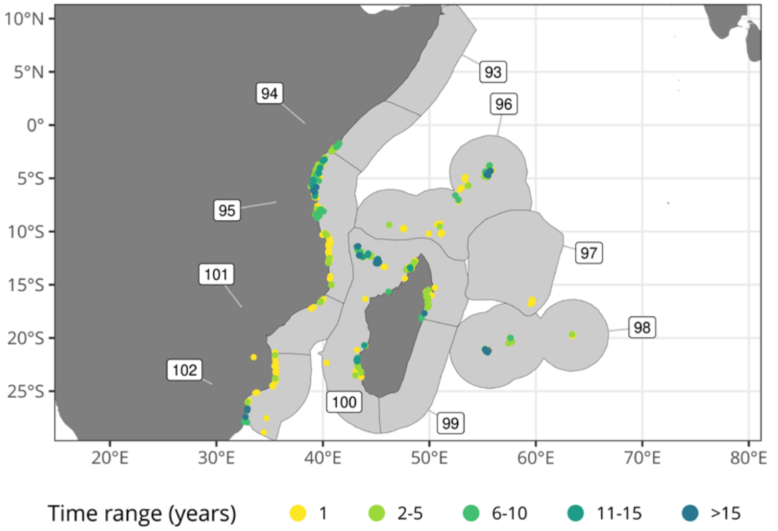

Figure 5.2. The distribution and duration of monitoring at sites across the Western Indian Ocean region. The colours of dots represent the time span between the first survey and the most recent survey at each site. Numbers refer to the MEOW ecoregions listed in Table 5.1.

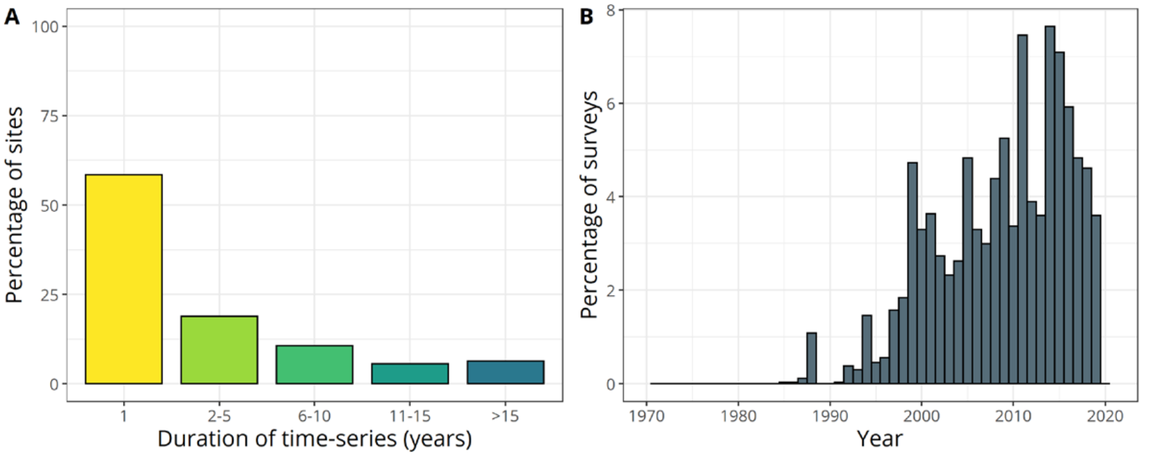

Figure 5.3. The proportion of sites in the Western Indian Ocean region within each category describing the time span between the first and most recent surveys (A), and the proportion of the total number of surveys conducted in each year (B). The total number of surveys was 2,642.

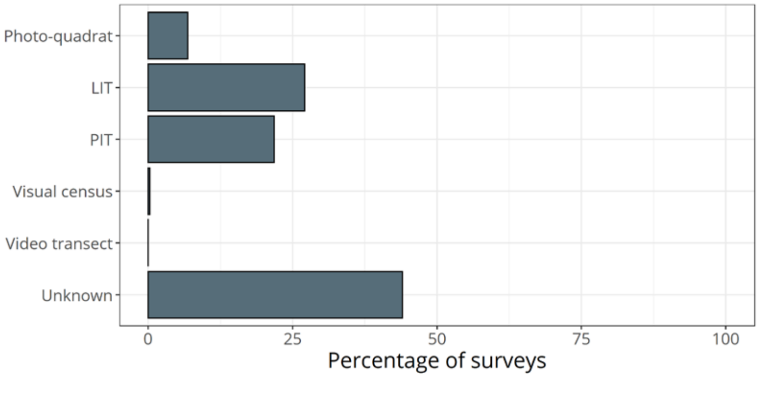

Figure 5.4. The proportion of the total number of surveys conducted in the Western Indian Ocean region using each survey method. PIT: Point Intercept Transect; LIT: Line Intercept Transect.

3. Status of coral reefs in the Western Indian Ocean region

- Regional trends in the cover of live hard coral and algae

Between 1985 and 1997, the estimated average cover of live hard coral was moderate and showed a gradual increasing trend from 26.2% to 28.8%, although there is considerable uncertainty in early estimates due to the paucity of data from this time (Fig. 5.5A). Following the El Niño and consequent global bleaching event of 1998, coral cover declined to 26.5% in 1999 and remained at similar levels until 2003. From 2004, reefs showed recovery, with an increasing trend in coral cover that peaked at 32.3% in 2012. In 2013 and 2017 two sharp declines were observed, reaching 29.4% in 2018-19. While data contributed to this analysis showed that current coral cover is higher than during the 1980s and 1990s, other published data not shared for this analysis show greater coral cover in the 1980s and 1990s (up to 40%), 45-70% coral mortality in 1998 and a failure to return to pre-existing levels[3,4].

The obvious declines in coral cover in this time-series clearly illustrate the impacts of the two major coral bleaching events (1998 and 2016) on the region (Fig. 5.5A). However, promisingly, it also highlights the capacity for reefs to recover after bleaching, if there is enough time between major disturbances. Other bleaching events have been documented in the region, but their signal in the regional dataset is obscured by different coral cover trajectories across the region.

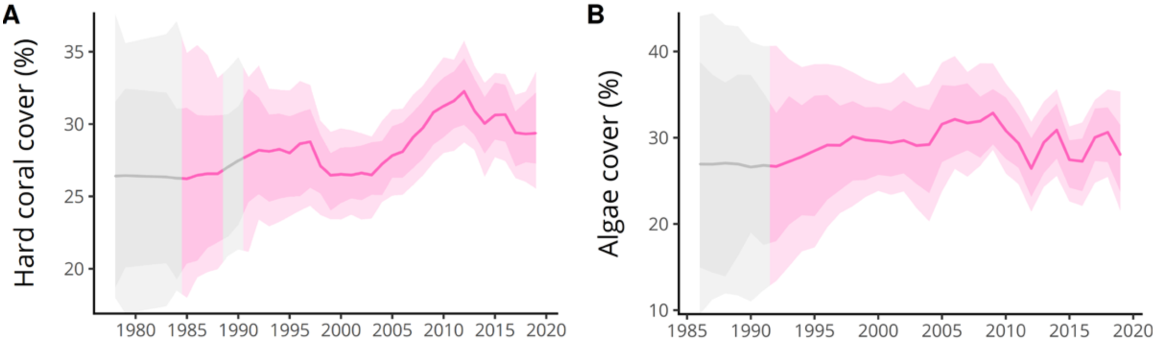

Figure 5.5. Estimated regional average cover of live hard coral (A) and algae (B) for the Western Indian Ocean region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available.

Comparisons of average hard coral cover between three five-year periods (2005-09, 2010-14, 2015-19) indicated that despite the uncertainty in individual yearly estimates, there was a reasonable probability (~84%) that hard coral cover has declined between 2010-14 and 2015-19 (Tab. 5.3). On average, the decline in the absolute cover of live hard coral between 2010-14 and 2015-19 was 1.4%, which represents a loss of 6.2% of the coral in the region. However, the decline between 2010-14 and 2015-19 was offset by an equally likely (~88%) and similar (1.3%) increase in hard coral cover between 2005-09 and 2010-14 (Tab. 5.3), which resulted from an uninterrupted period of recovery from a low baseline. The net result is little change in average coral cover at a regional scale during the last 15 years. The paucity of data prior to 2005 (globally) prevents this analysis for prior years.

[3] McClanahan T, Muthiga N, Mangi S (2001) Coral and algal changes after the 1998 coral bleaching: interaction with reef management and herbivores on Kenyan reefs. Coral Reefs 19:380–391. https://doi.org/10.1007/s003380000133

[4] Ateweberhan M, McClanahan TR, Graham NAJ, Sheppard CRC (2011) Episodic heterogeneous decline and recovery of coral cover in the Indian Ocean. Coral Reefs 30:739–752. https://doi.org/10.1007/s00338-011-0775-x

Table 5.3. Probability and magnitude of mean absolute and relative change in the percent cover of live hard coral in the Western Indian Ocean region between each of the three five-year periods comprising the last 15 years.

Comparison	Probability of change (%)	Mean absolute change (%)	Mean relative change (%)
2005-09 - 2010-14	88	1.3	6.6
2010-14 - 2015-19	84	-1.4	-6.2
2005-09 - 2015-19	52	-0.1	-0.2

The trend in algal cover over the last 27 years is less clear than that of hard coral cover (Fig. 5.5B). While uncertainty in early estimates is substantial because fewer data were available and there were inconsistencies in monitoring and classifying different types of algae (including macroalgae and turf assemblages), the cover of algae on WIO reefs generally increased from 26.7% in 1992, when the first algal cover data were collected, to a peak of 32.9% in 2009 (Fig. 5.5B). However, after 2009, the cover of algae fluctuated considerably (Fig. 5.5B), yet there was no evidence (53%) of an overall change between 2010-14 and 2015-19 (Tab. 5.4). Similarly, there was little overall difference in the average cover of algae across the WIO region when comparing the earliest estimate (26.7% in 1992) with the most recent estimate (28% in 2019). The cover of algae has remained moderately high compared with other GCRMN regions that have similar hard coral cover to the WIO.

Table 5.4. Probability and magnitude of mean absolute and relative change in the percent cover of algae in the Western Indian Ocean region between each of the three five-year periods comprising the last 15 years.

Comparison	Probability of change (%)	Mean absolute change (%)	Mean relative change (%)
2005-09 - 2010-14	91	-3.2	-13.4
2010-14 - 2015-19	53	0.3	2.0
2005-09 - 2015-19	88	-2.9	-12.1

- The primary causes of change in the cover of live hard coral and algae

Within the WIO region, widespread decline in live coral cover following global bleaching events occurred in 1998 and 2016[5,6]. Less significant bleaching events occurred in 1983, 2005, 2007 and 2010, but with varying bleaching severity and mortality among subregions, and no impacts visible at the regional level. These periods of thermal stress have interacted strongly with fishing and various local environmental stressors[7,1], producing complex patterns of decline and partial recovery.

All but one of the long-term monitoring sites (i.e. sites monitored over periods > 15 years, Tab. 5.2) considered here were established since the 1998 coral bleaching event. As a consequence, none of these sites experienced a 20% decline in relative coral cover between the first and last survey, which made it difficult to examine patterns of disturbance and recovery and potential changes to the resilience of coral reefs in the region (see analysis in other regional chapters). The longest time series (1993-2014) was collected from a high latitude reef in South Africa which has not been impacted by the regional bleaching events and has shown an increase in hard coral over time[8]. The 2017 GCRMN WIO report found that coral cover declined in 1998 by 25%[1], corresponding to earlier findings[5,4]. Citizen science surveys conducted

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[6] Gudka M, Obura D, Mbugua J, et al (2020) Participatory reporting of the 2016 bleaching event in the Western Indian Ocean. Coral Reefs 39:1–11. https://doi.org/10.1007/s00338-019-01851-3

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after the coral bleaching event in 2016 found 20% of sites showed high to extreme mortality exceeding 50% of corals[6], which corresponded with the decline in coral cover from 30.7% in 2016 to 29.4% in 2017 shown here (Fig. 5.5A). It is likely that, had data from long term monitoring sites established prior to 1998 been contributed to these analyses, they would show a decline in coral reef health and failure to recover back to pre-1998 levels of hard coral cover, rather than the apparent improvement shown in Figure 5.5A.

- Changes in resilience of coral reefs within the Western Indian Ocean region

Recent studies on other pressures and key processes driving coral reef health in the WIO include studies of coral reproduction[9,10], coral disease[11], fish and fishery dynamics[12,13], genetic connectivity[14] and transport by currents[15,16]. These factors will influence the resilience and response of coral reefs to climate threats[17], particularly as several subregions within the WIO are projected to have among the most favourable climates for coral survival compared with other subregions here, and globally[18]. To date, some reefs have shown reasonable recovery in the 18-year period between the two major bleaching events in 1998 and 2016, notably in the Seychelles[19], which is evident in the upward trend between 2000 and 2010 in Figure 5.6. There is a clear signal of shifting coral community structure, with loss of susceptible coral species and loss of diversity[20], though some acclimation and/or adaptation of corals to warming may have occurred following multiple bleaching events, as shown in Mayotte[21]. This provides some hope that with adequate measures to minimise local threats, reefs in climatically favourable subregions may have a chance to keep up with warming conditions[22]. However, the increasing frequency and intensity of heat stress globally[23] and intensification of other pressures locally may overwhelm such capacities for adaptation unless strong actions are taken to reduce all threats.

[9] Mangubhai S (2009) Reproductive ecology of the scleractinian corals Echinopora gemmacea and Leptoria phrygia (Faviidae) on equatorial reefs in Kenya. Invertebrate Reproduction and Development 53:67–79

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[18] UNEP 2020. Projections of future coral bleaching conditions using IPCC CMIP6 models: climate policy implications, management applications, and Regional Seas summaries. United Nations Environment Programme, Nairobi, Kenya

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[22] McClanahan TR, Muthiga NA (2017) Environmental variability indicates a climate-adaptive center under threat in northern Mozambique coral reefs. Ecosphere 8:e01812. https://doi.org/10.1002/ecs2.1812

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4. Subregional trends in the cover of live hard coral and algae within the Western Indian Ocean region

Within the WIO region, the trends in hard coral cover among the five different subregions varied, indicating heterogeneity in exposure to disturbances which affected recovery patterns of reefs among subregions (Figs. 6 & 7). Subregions 2 (Seychelles) and 3 (Mascarene Islands) showed general and steady declines, while subregion 1 (N Mozambique - Somalia) showed temporal changes most consistent with the broader regional-scale trend. Subregion 5 (Delagoa) showed a steady and gradual increase in hard coral cover post-1998 and subregion 4 (Madagascar and Comoros) showed increased coral cover until 2012 and then subsequent decline.

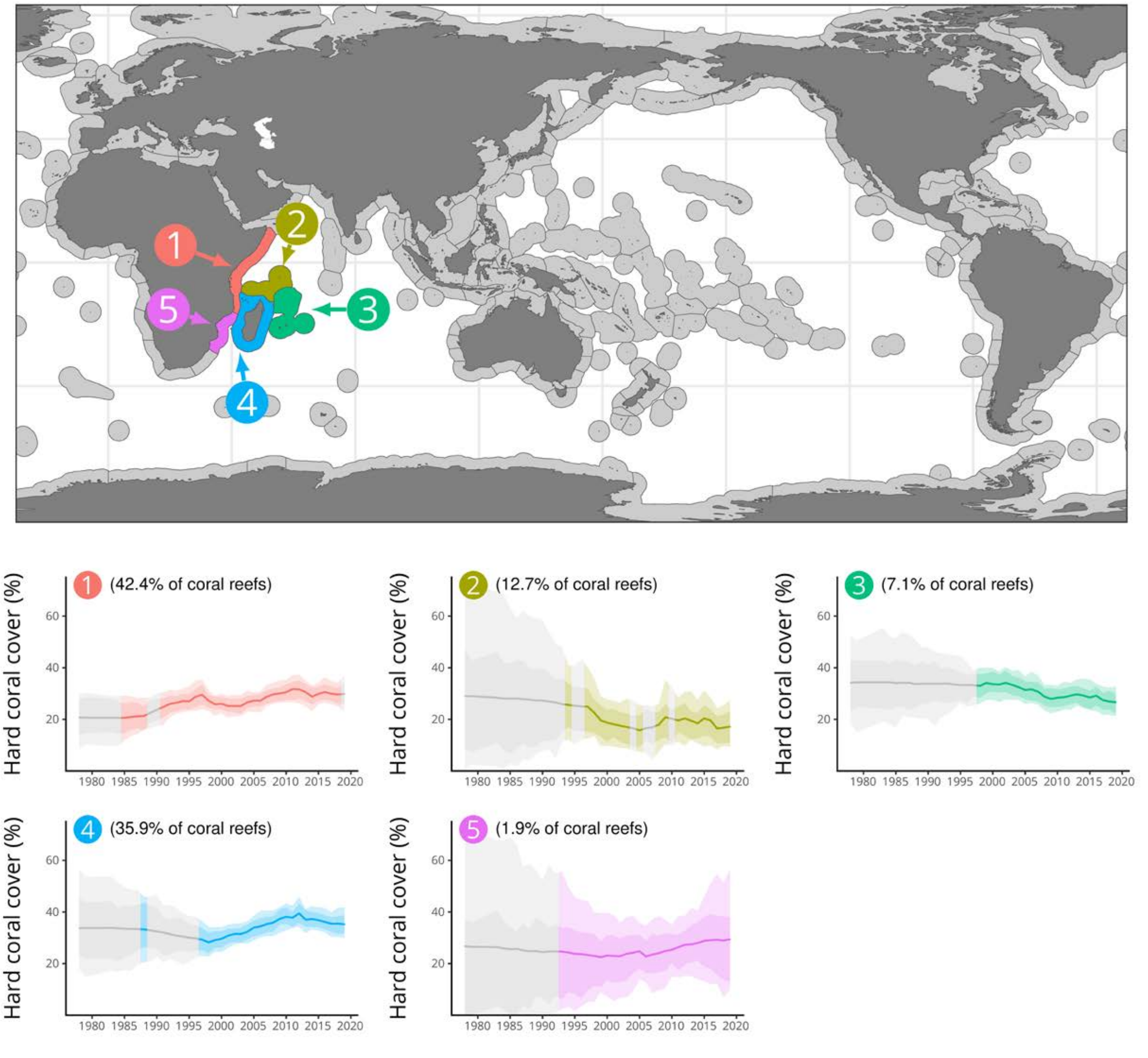

Figure 5.6. Estimated average cover of live hard coral within each subregion comprising the Western Indian Ocean region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available. The proportion of all coral reefs in the Western Indian Ocean region within each subregion is indicated by the % of coral reefs.

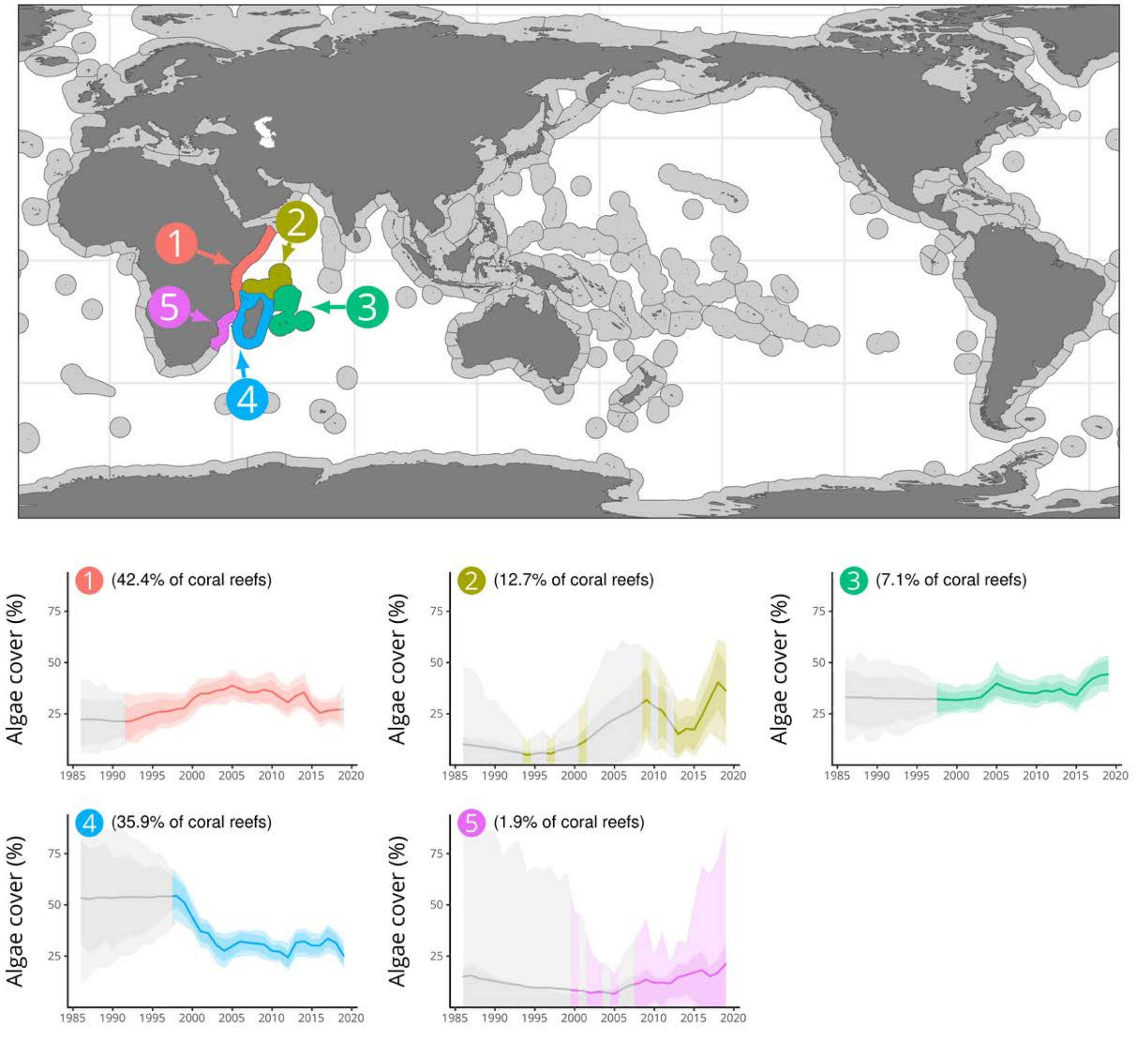

Figure 5.7. Estimated average cover of algae within each subregion comprising the Western Indian Ocean region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available. The proportion of all coral reefs in the Western Indian Ocean region within each subregion is indicated by the % of coral reefs.

Box 3.

The IUCN Red Lists of corals and coral reef ecosystems

David Obura and Mishal Gudka, CORDIO East Africa and IUCN Coral Specialist Group

The IUCN Red List of species was established over 50 years ago[1], and assesses the risk of extinction of species. Reef-building corals were first assessed in 2008, when one-third of species were listed as Threatened with extinction[2]. The assessment is being updated through the IUCN Coral Specialist Group (https://www.coralspecialistgroup.org/), which is currently assessing over 950 species compared with 854 assessed in 2008. The assessment has used a new fully-online process for assessment due to cost constraints, and the COVID-19 pandemic. Close to 100 participants have been involved, using online tools to remotely compile the new species assessments. Results will be completed during 2022.

The Red List of ecosystems (RLE, www.iucnrle.org) was developed in the last decade, applying similar principles and approaches to assess the risk of collapse of ecosystems[3,4]. Coral reefs in the Western Indian Ocean (WIO) and in 11 nested ecoregions were assessed by comparing GCRMN data describing the current covers of hard coral and fleshy algae, parrotfish and grouper abundance with estimated baselines of 50 years ago. Projected SSTs generated by UNEP[5] were also used to assess risk of collapse in 50 years time. The results, in which 10 nested ecoregions were assessed as Vulnerable and Critically Endangered, indicated higher threat levels than those indicated in this report, primarily because of the inclusion of fish abundance data and direct assessment of the worsening climate threat in the next 50 years.

Both species and ecosystem Red Lists used data aggregated and reported through the GCRMN, delivering under goals 2 (informing policy and decisions) and 3 (promote greater utilization of coral reef data) of the GCRMN Implementation and Governance Plan. For the

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global Red List of coral species analysis, the regional and subregional results presented in this report provided estimates of percent decline in coral cover (for most species for a period of 30 years), which were then mapped against individual species distributions. For the regional RLE analysis, the GCRMN network in the WIO updated and re-analyzed its primary data, developing a method that can be replicated in all other GCRMN regions.

The Red List of species is the premier biodiversity metric informing global conventions and United Nations processes. Both CORDIO, through the IUCN RLE Partnership, and the International Coral Reef Initiative have promoted the use of the RLE as a primary indicator in the Global Biodiversity Framework of the Convention on Biological Diversity (CBD). The IUCN RLE Partnership aims to replicate the regional coral reef RLE across all GCRMN regions in the next 2-3 years, based on the global coverage of data in this GCRMN report. This will strengthen the provision of standardized biodiversity metrics in the CBD and other convention processes, including for the Sustainable Development Goals, providing more nuanced and policy-relevant indicators of the status of coral reefs globally, and their provision of services to people.

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