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Status of Coral Reefs of the World: 2020

Chapter 11. Status and trends of coral reefs of the Brazil region

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Chapter 11.

Status and trends of coral reefs of the Brazil region

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1. Geographic information and context

Key numbers:

- Total area of coral reefs: 1.226 km^2
- Proportion of the world's coral reefs: 0.47%
- Number of countries with coral reefs: 1
- Number of Marine Ecoregions of the World (MEOW) ecoregions: 4

Regional Context:

Brazil supports the only coral reefs in the South Atlantic, spread along 3,000 km of the coast, from 0°50'S to 18°00'S[1]. The continental shelf is carbonatic and narrow along most of its length. Coral reef formations grow parallel to the coast, including fringing as well as long bank reefs[2]. The continental shelf widens in the south at Abrolhos Bank, which is the largest coral reef formation in the region. Coral reef formations are also found on oceanic islands and banks, and on the Fernando de Noronha chain lies the Rocas Atoll, the only atoll in the South Atlantic Ocean[3]. Isolated coral formations occur in the north in the Parcel Manuel Luis in Maranhao (0° 50' S) and occur as far as São Paulo state (24°0' S)[1,4].

Coral reef formations in Brazil are unique both in form and species composition, growing in unique mushroom shapes (chapeirão) that may form pinnacles 20 m high, such as the Abrolhos "chapeirões", or extensive reef tops in shallow areas, by expanding laterally and coalescing in the top[2,3]. Low diversity (23 species of hard coral and five species of hydrocoral) and strong endemism (nine of 28 species are endemic) are distinct characteristics of Brazilian coral reefs[1].

[1] Leão, Z. M., Kikuchi, R. K., Ferreira, B. P., Neves, E. G., Sovierzoski, H. H., Oliveira, M. D., Maida, M., Correia, M. D., & Johnsson, R. (2016). Brazilian coral reefs in a period of global change: A synthesis. Brazilian Journal of Oceanography, 64(SPE2), 97-116.

[2] Leão, Z. M., Kikuchi, R. K., & Testa, V. (2003). Corals and coral reefs of Brazil. In Latin American coral reefs (pp. 9-52). Elsevier Science.

[3] Maida, M., & Ferreira, B. P. (1997). Coral reefs of Brazil: an overview. In Proceedings of the 8th international coral reef symposium (Vol. 1, No. 263, p. 74). Smithsonian Tropical Research Institute Panamá.

[4] Pereira-Filho, G. H., Shintate, G. S., Kitahara, M. V., Moura, R. L., Amado-Filho, G. M., Bahia, R. G., & Motta, F. S. (2019). The southernmost Atlantic coral reef is off the subtropical island of Queimada Grande (24 S), Brazil. Bulletin of Marine Science, 95(2), 277-287.

Present time mesophotic reefs were formed during sea level fluctuations, with transgressive and regressive seas marking different stages of reef development[1,2]. Those give-up reefs, formed during the last low sea level period, are present along the outer shelf from the Amazon, where extensive reefs have been described[5,6], to the whole north-eastern coast where they have been classified as an Ecologically or Biologically Significant Marine Area by the Convention of Biological Diversity[7]. Those deep reefs are part of the coralline seascape, represent a faunal corridor and are interconnected by many populations of reef fish[8].

The coastal zone is home to 25 million inhabitants, with most large cities located along the coast. Coastal reefs that emerge on lower tides are an important feature of this region, inspiring city names like Recife (*reef* in Portuguese), providing coastal protection and most of the catches of the artisanal fisheries that dominate the region. Tourism is a growing industry in the region, with clear waters and coral reefs being the main attraction. Main reef areas are part of marine protected areas (MPAs), such as Rocas Atoll and Fernando de Noronha Island, Abrolhos Bank and the Coral Costa MPA, although strict protection is still very low and presently threatened by increasing pressures[9].

The Brazil region is located in the South Western Atlantic and includes four Marine Ecoregions of the World (MEOW) ecoregions[10] (Tab. 11.1, Fig. 11.1). In subregion 1, sites were located at Rocas Atoll and Fernando de Noronha Archipelago, which are both fully protected (no-take) MPAs. Subregion 2 includes the coastal reefs of the north-eastern region, with sites located at two sustainable-use MPAs, the Coral Reef MPA and the Coral Coast MPA. Subregion 3 includes Porto Seguro reefs and the Abrolhos Marine Park, which is a fully protected MPA.

Table 11.1. The subregions comprising the Brazil region, the area of reef they support, and the constituent Marine Ecoregions of the World (MEOW)

Subregion	Reef Area (km^2)*	Proportion of reef area within the Brazil region(%)	Constituent Marine Ecoregions of the World
1	10	0.8	074: Fernando de Noronha and Atol das Rocas
2	349	28.5	075: Northeastern Brazil
3	730	59.5	076: Eastern Brazil 077: Trindade and Martin Vaz Islands**
4	137	11.2	071: Guianan** 072: Amazonia**

***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**

[5] Moura, R. L., Amado-Filho, G. M., Moraes, F. C., Brasileiro, P. S., Salomon, P. S., Mahiques, M. M., ... & Thompson, F. L. (2016). An extensive reef system at the Amazon River mouth. Science advances, 2(4), e1501252.

[6] Francini-Filho, R. B., Asp, N. E., Siegle, E., Hocevar, J., Lowyck, K., D'Avila, N., Vasconcelos, A. A., Batielo, R., Rezende, C. E., Omachi, C. Y., Thompson, C. C., & Thompson, F. L. (2018). Perspectives on the Great Amazon Reef: extension, biodiversity, and threats. Frontiers in Marine Science, 5, 142.

[7] CDB - Secretariat of the Convention on Biological Diversity. (2014). Ecologically or Biologically Significant Marine Areas (EBSAs): Special places in the world's oceans. Volume 2: Wider Caribbean and western Mid-Atlantic region. Montreal, QC, Canada: Secretariat of the Convention on Biological Diversity

[8] Olavo, G., Costa, P. A., Martins, A. S., & Ferreira, B. P. (2011). Shelf-edge reefs as priority areas for conservation of reef fish diversity in the tropical Atlantic. Aquatic conservation: marine and freshwater ecosystems, 21(2), 199-209.

[9] Magris, R. A., Mills, M., Fuentes, M. M. P. B., & Pressey, R. L. (2013). Analysis of progress towards a comprehensive system of marine protected areas in Brazil. Nat. Conserv, 11(1), 1-7.

[10] 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

**No data were received from this subregion.

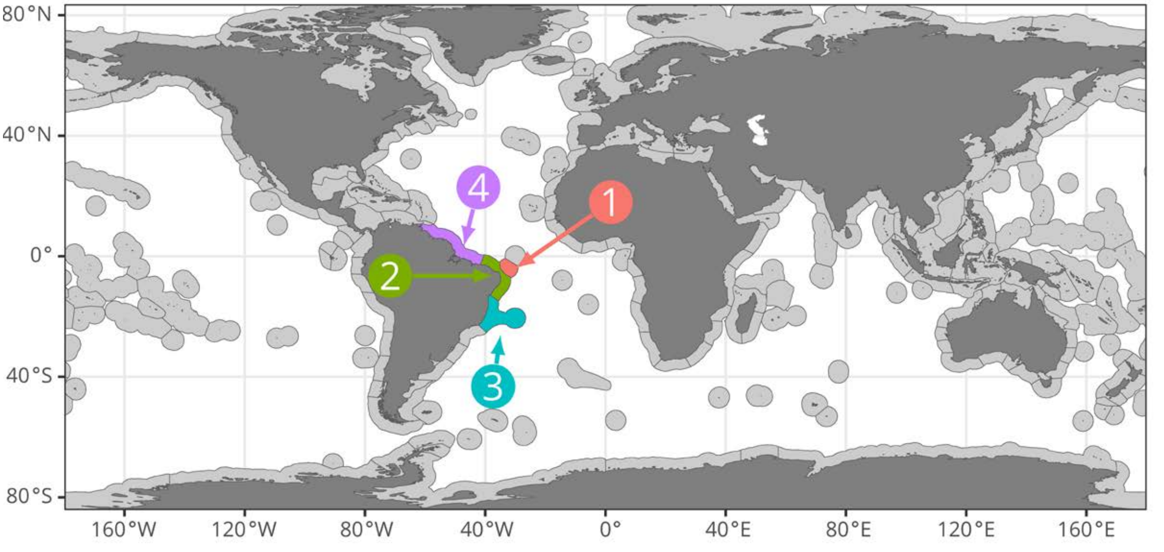

Figure 11.1. Map of each subregion comprising the Brazil region. The number ascribed to each subregion corresponds with that in Table 11.1.

2. Summary of data contributed to this report

Key numbers:

- Number of countries from which monitoring data were used: 1 (of 1)
- Number of sites: 35
- Number of observations: 6,308
- Longest time series: 16 years

General features:

The status and trends of Brazilian coral reefs presented below are based on more than 6,300 observations collected as part of a national coral reef monitoring program that commenced in 2002. Using a Reef Check compatible protocol, 35 sites distributed between 3°5'S and 18°0'S[11] (Tab. 11.2) have been surveyed, with some sites being regularly monitored until 2018-2019. Coral cover data were collected exclusively using point intercept transects (Fig. 11.4), and include both scleractinian hard corals and milleporid hydrocorals, which are the only reef-building branching forms present on Brazilian reefs[12]. These data comprise 0.65% of the global dataset that underpins this GCRMN *Status of Coral Reefs of the World: 2020* report.

The distribution of monitoring effort across Brazilian reefs reflects different local conditions and support for the national monitoring program at different times. The monitoring effort was distributed across the different areas, with the largest number of surveys conducted in subregion 2 due to the

[11] Ferreira, B. P.; Gaspar, A. L. B.; Coxey, M. S.; Monteiro, A. C. G. (2018). Manual de Monitoramento Reef Check Brasil 2018. Ministério do Meio Ambiente, Brasília, DF. Available online: http://www.mma.gov.br/publicacoes/

[12] Coni, E. O. C., Ferreira, C. M., de Moura, R. L., Meirelles, P. M., Kaufman, L., & Francini-Filho, R. B. (2013). An evaluation of the use of branching fire-corals (Millepora spp.) as refuge by reef fish in the Abrolhos Bank, eastern Brazil. Environmental Biology of Fishes, 96(1), 45-55.

long-term support of ongoing projects.

Monitoring sites are generally located within MPAs and have been surveyed between seven and 12 times since 2002. The number of surveys conducted was greater in 2005, 2007, 2009/2010 and 2016 (the last two corresponding with El Niño periods), with monitoring occurring at more than 20 sites (Fig. 11.3B).

Long-term monitoring (>15 years between the first survey and the most recent survey) occurred at nine sites within the Brazilian region, with each site being surveyed over a period of 16 years (Tab. 11.2, Fig. 11.2 and 3A).

Table 11.2. Summary statistics describing data contributed from the Brazil 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.

Brazil 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	6,308	0.65	35	0.29	9	1.53
1	1,755	0.18	11	0.09	4	0.68
2	2,487	0.26	12	0.1	1	0.17
3	2,066	0.21	12	0.1	4	0.68
4	0	0	0	0	0	0

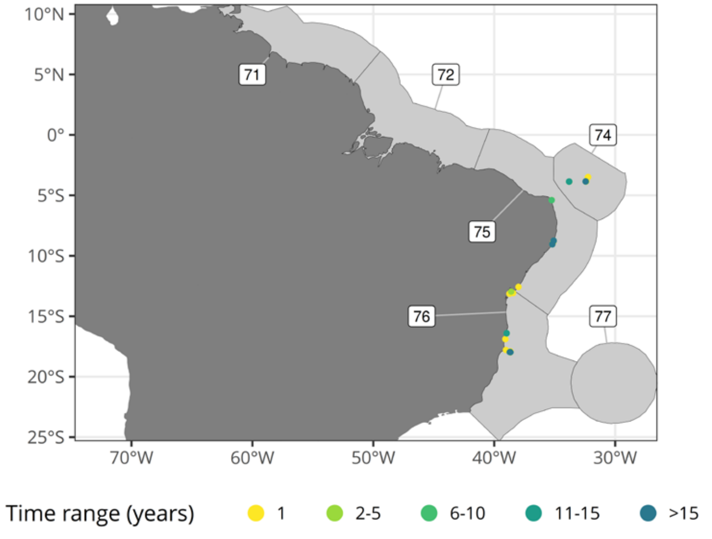

Figure 11.2. The distribution and duration of monitoring at sites across the Brazil region. The colours of dots represent the time span between the first survey and the most recent survey at each site. Numbers refer to the MEOW ecoregions listed in Table 11.1.

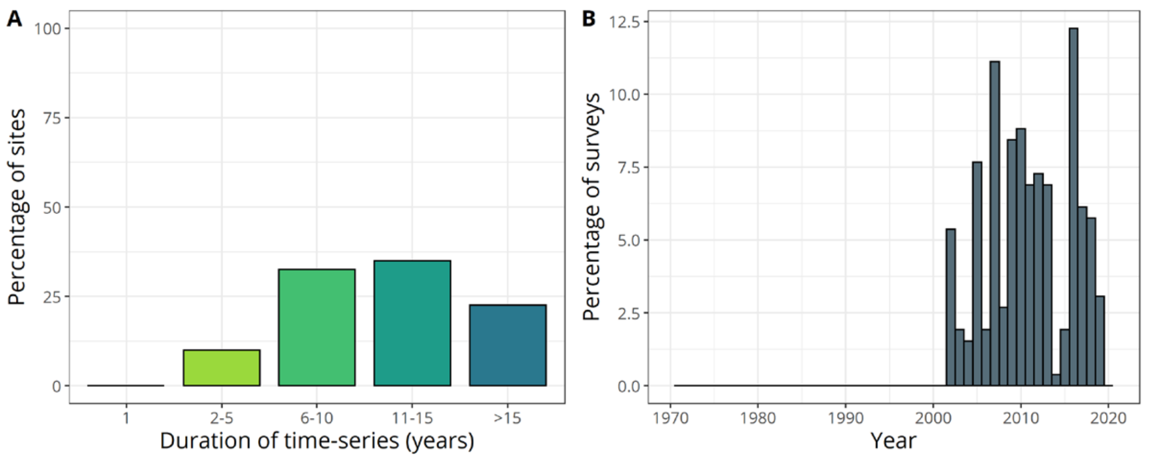

Figure 11.3. The proportion of sites in the Brazil region within each category describing the time span between the first and most recent surveys (A), and the proportion of the total number of surveys conducted in each year (B). The total number of surveys was 261.

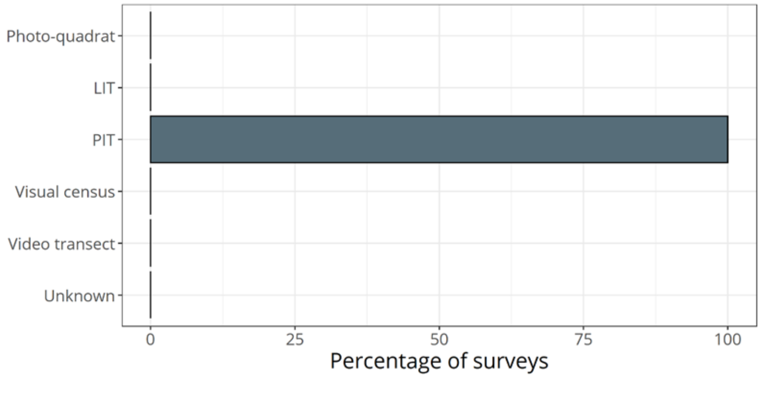

Figure 11.4. The proportion of the total number of surveys conducted in the Brazil region using each survey method. PIT: Point Intercept Transect; LIT: Line Intercept Transect.

3. Status of coral reefs in the Brazil region

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

The trend in average hard coral within the Brazil region fluctuated, initially declining from 19.1% in 2002, when the first data were collected, to 16.3% in 2005, before increasing to 28.9% in 2016 (Fig. 11.5A). Between 2016 and early 2019, a sharp decline in average coral cover to 20.6% was observed. This pattern was largely driven by the eastern subregion (subregion 3), which supports the largest area of reefs in the region (Tab. 11.1).

The average cover of algae almost doubled during the last 15 years. An initial increase occurred between 2002 and 2008 when the average cover of algae increased from 19.5% to 29.1% (Fig. 11.5B). Between 2009 and 2014, the cover of algae remained reasonably stable ranging between 30% (2010) and 27.5% (2014). Since 2015, the average cover of algae has progressively increased to 37% in 2019 (Fig. 11.5B).

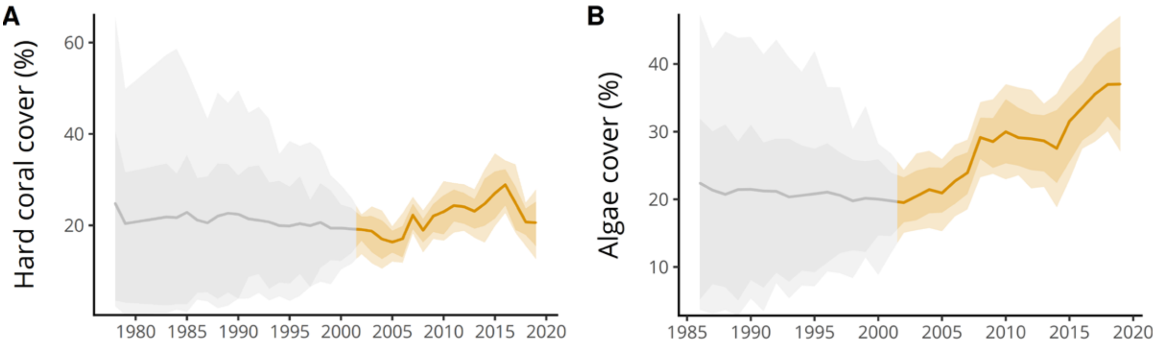

Figure 11.5. Modelled cover of live hard coral (A) and algae (B) for the Brazil Region. The solid line represents the predicted marginal mean and ribbons represent 80% (lighter shade) and 95% (darker shade) credible intervals. Grey areas of the temporal series represent times for which no observed data were available.

Comparisons of the average hard coral cover between the three five-year periods comprising the last 15 years (2005-09, 2010-14, 2015-19) showed that there was a high probability (92-98%) that coral cover had increased between 2005-09 and 2010-14 (4.1% average absolute change) and overall between 2005-09 and 2015-19 (3.0% average absolute change), representing relative increases of 27.0% and 20.3% respectively (Tab. 11.3). However, between 2010-14 and 2015-19, there was weak evidence (69.3% probability) of a decline, which is consistent with possible effect of the mass bleaching event observed during the 2016 El Niño[13].

Table 11.3. Probability and magnitude of mean absolute and relative change in the percent cover of live hard coral in the Brazil 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	98	4.1	27
2010-14 - 2015-19	69	-1.0	-4.6
2005-09 - 2015-19	92	3.0	20.3

Comparisons of the average cover of algae over the same three five-year periods showed a moderate probability (88%) of an increase in the cover of algae between 2005-09 and 2010-14, but that there was a very strong probability of an increase between 2010-14 and 2015-19 (99%) and over the longer term

13 Teixeira, C. D., Leitão, R. L., Ribeiro, F. V., Moraes, F. C., Neves, L. M., Bastos, A. C., Pereira-Filho, G. H., Kampel, M., Salomon, P. S., Sá, J. A., Falsarella, L. N., Amario, M., Abieri, M. L., Pereira, R. C., Amado-Filho, G. M., & Moura, R. L. (2019). Sustained mass coral bleaching (2016–2017) in Brazilian turbid-zone reefs: taxonomic, cross-shelf and habitat-related trends. Coral Reefs, 38(4), 801-813.

between 2005-09 and 2015-19 (100%) (Tab. 11.4). On average, absolute increases in algal cover were considerably greater between 2010-14 and 2015-19 (6.6%) than between 2005-09 and 2010-14 (2.4%). Despite some variation between individual sites and the greater contribution of the eastern subregion (subregion 3) to the analysis, the substantial overall trend suggested that there was, on average, 57% more algae on reefs in the region in 2015-19 compared with 2005-09 (Tab.4) . This pattern was consistent with trends observed in subregions 1 and 3, while in subregion 2 there was little net change despite considerable fluctuations in algal cover since monitoring began in 2002 (Fig. 11.7).

Table 11.4. Probability and magnitude of mean absolute and relative change in the percent cover of algae in the Brazil 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	2.4	10.4
2010-14 - 2015-19	99	6.6	43.5
2005-09 - 2015-19	100	9.0	57.1

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

Historically, chronic land-based threats such as sedimentation and pollution have been the major cause of coral loss on coastal reefs of the Brazilian region[2,3,14], with oceanic and shelf reefs being less affected. In the last decade, increased intensity and frequency of El Niño Southern Oscillation (ENSO) events have overshadowed those threats, with stronger and more widespread events causing mass coral bleaching and affecting coral and algal cover on Brazilian coral reefs. ENSO events impacted Brazilian reefs during 2003, 2005, 2010 and 2016, causing bleaching and mortality, which varied in intensity depending on subregion and local characteristics[13,15,16,17,18].

The moderate El Niño event of 2010 was the first to affect the entire region since the 1998 El Niño. This event caused bleaching in all subregions and although subsequent coral mortality was low[18,19], an increase in the prevalence of diseases was observed at oceanic sites[17]. The eastern subregion (subregion 3) was the most affected by the large-scale global warming event of 2016, which caused mass coral bleaching but low subsequent mortality[13,20].

Conversely, algal cover has been increasing during the last two decades, particularly in the oceanic (subregion 1) and the eastern (subregion 3) subregions. The causes of those increases were unclear but could be associated with eutrophication and intensification of warming events. More studies are

[14] Dutra, L. X. C., Kikuchi, R. K. P., & Leão, Z. M. A. N. (2006). Effects of sediment accumulation on reef corals from Abrolhos, Bahia, Brazil. Journal of Coastal Research, 633-638.

[15] Kikuchi, R. K., Leão, Z. M., & Oliveira, M. D. (2010). Conservation status and spatial patterns of AGRRA vitality indices in Southwestern Atlantic Reefs. Revista de biologia tropical, 58, 10-32.

[16] Leão, Z. M. A. N., Kikuchi, R. K., Oliveira, M. D., & Vasconcellos, V. (2010). Status of Eastern Brazilian coral reefs in time of climate changes. Pan-American Journal of Aquatic Sciences, 5(2), 224-35.

[17] Ferreira, B. P., Costa, M. B. S. F., Coxey, M. S., Gaspar, A. L. B., Veleda, D., & Araujo, M. (2012). The effects of sea surface temperature anomalies on oceanic coral reef systems in the southwestern tropical Atlantic. Coral reefs, 32(2), 441-454.

[18] Miranda, R. J., Cruz, I. C., & Leão, Z. M. (2013). Coral bleaching in the Caramuanas reef (Todos os Santos Bay, Brazil) during the 2010 El Niño event. Latin American Journal of Aquatic Research, 41(2), 351-360.

[19] Lisboa, D. S., Kikuchi, R. K. P., & Leão, Z. M. (2018). El Nino, sea surface temperature anomaly and coral bleaching in the South Atlantic: A chain of events modeled with a Bayesian approach. Journal of Geophysical Research: Oceans, 123(4), 2554-2569.

[20] Duarte, G. A., Villela, H. D., Deocleciano, M., Silva, D., Barno, A., Cardoso, P. M., ... & Peixoto, R. S. (2020). Heat waves are a major threat to turbid coral reefs in Brazil. Frontiers in Marine Science, 7, 179.

necessary to understand the complex patterns of algal dynamics[21].

- Changes in resilience of coral reefs within the Brazil region

To identify changes in the resilience of coral reefs in the Brazil region, patterns of disturbance and recovery were examined within sampling units that had been surveyed repeatedly over a period of at least 15 years and had, at some point, experienced a relative decline in hard coral cover of at least 20%. Of the 11 such sampling units, more than half (7) did not recover to at least 90% of their pre-disturbance hard coral cover (Tab. 11.5). The average decline in hard coral cover between the first and most recent surveys within these sampling units was almost 6% representing a loss of 17.2% of the existing hard coral cover. The average maximum absolute decline in hard coral cover within these sampling units was 10.4%, which represents a relative loss of 38.8% of hard coral (Tab. 11.5).

Increases in the frequency of bleaching events may lead to direct or indirect coral mortality, due to the prevalence of diseases and competition with algae. Prior to 2016, bleaching-associated coral mortality on Brazilian coral reefs was low compared with other regions of the world, suggesting that these reefs might represent a thermal refuge[21,22]. More recently however, the 2019-2020 coral bleaching event, caused by a massive marine heat wave[20], caused widespread bleaching across all subregions, with estimated mortality exceeding 50% for some species, according to local reports[23,24] and our own observations which were obtained after the data collation period for this report. Coral mortality associated with the 2019-2020 event was the greatest ever recorded in Brazil and it marked a shift in the prevalent view that Brazilian marginal reefs were less vulnerable to global climate patterns. This contrasts with the relative stability observed until now, and highlights both the importance of continuous monitoring and local management measures to mitigate predicted impacts.

Table 11.5. The mean maximum decline and the mean difference between first and last survey expressed as absolute and relative declines in percent live coral cover. N is the total number of sampling units for which >15 years of data were available and had experienced a relative decline in live coral cover of at least 20 percent. n is the number of sampling units that did not exhibit recovery to 90 percent of the initial live coral cover. Percent is the proportion of the total number of sampling units that did not exhibit recovery to 90 percent of the initial live coral cover. A sampling unit is defined as the specific area that was surveyed repeatedly. Depending on the survey methods used and how the data were provided, a sampling unit could be a transect, a quadrat or even a site.

N	n	Percent	Mean maximum absolute decline	Mean maximum relative decline	Mean long-term absolute decline	Mean long-term relative decline
11	7	63.6	10.4	38.8	5.8	17.2

[21] Teixeira C. D., Chiroque-Solano P. M. , Ribeiro F. V., Carlos-Júnior L. A., Neves L. M., Salomon P. S, et al. (2021) Decadal (2006-2018) dynamics of Southwestern Atlantic's largest turbid zone reefs. PLoS ONE 16(2): e0247111. https://doi.org/10.1371/journal.pone.0247111

[22] Mies, M., Francini-Filho, R. B., Zilberberg, C., Garrido, A. G., Longo, G. O., Laurentino, E., ... & Banha, T. N. (2020). South Atlantic coral reefs are major global warming refugia and less susceptible to bleaching. Frontiers in Marine Science, 7, 514.

[23] Ferreira, L. C. L, Grillo, A. C., Repinaldo Filho, F. P. M., Negrao, F., & Longo, G. O. (2021). Different responses of massive and branching corals to a major heatwave at the largest and richest reef complex in South Atlantic. Mar Biol 168, 54 (2021). https://doi.org/10.1007/s00227-021-03863-6

[24] Gaspar, T. L., Quimbayo, J. P., Ozekoski, R., Nunes, L. T., Aued, A. W., Mendes, T. C., Garrido, A. G., & Segal, B. (2021). Severe coral bleaching of Siderastrea stellata at the only atoll in the South Atlantic driven by sequential Marine Heatwaves. Biota Neotropica, 21(2).

4. Subregional trends in the cover of live hard coral and algae within the Brazil region

For the Brazilian region, the trends in hard coral cover among the three different subregions varied, indicating some heterogeneity in exposure to disturbance and recovery related to local conditions, including coral communities present in each subregion.

Subregions 1 and 3 showed a decline in average hard coral cover, with subregion 1 showing a gradual but steady decrease, and subregion 3 showing more oscillations through time with a sharper decline in the last five years (Fig. 11.6). At oceanic sites (subregion 1), it is worth noting that coral cover decrease was recorded mainly in shallow areas. In subregion 2, which supports about a third of the coral reefs of Brazil and where most sites are located near the coast, coral cover increased, while algal cover remained stable. Increased protection, through the control of damage by fishing and tourism inside MPAs and the prohibition of collection and trade in corals, has helped to maintain and improve coral cover, mainly due to recovery and growth of milleporids.

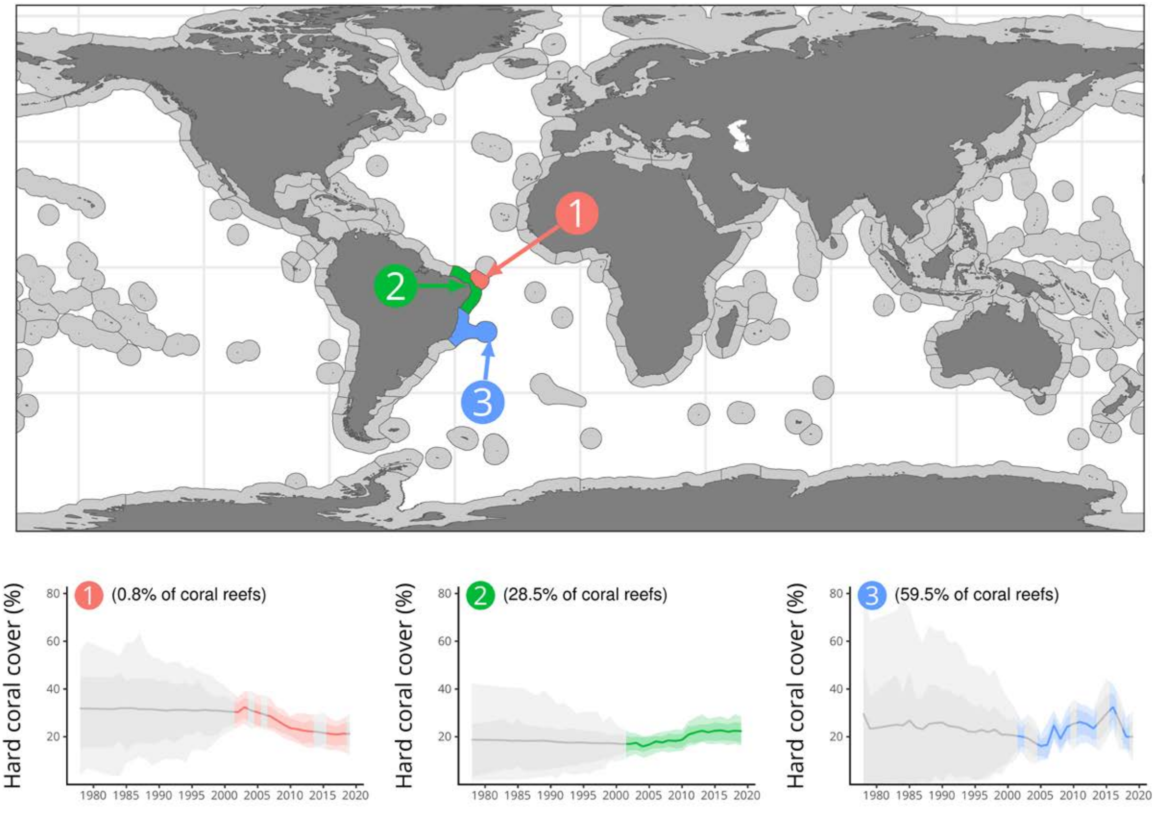

Figure 11.6. Estimated average cover of live hard coral within each subregion comprising the Brazil region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available. The proportion of all coral reefs in the Brazil region within each subregion is indicated by the % of coral reefs.

Similar to hard coral cover, trends in the cover of algae varied among different subregions (Fig. 11.7). Subregions 1 and 3 showed an increase in the average cover of algae, especially in the last decade during which time it almost doubled in subregion 1 (Fig. 11.7). This trend could be related to warming conditions observed over the same period. In subregion 2, the average cover of algae has remained relatively stable during the last 15 years.

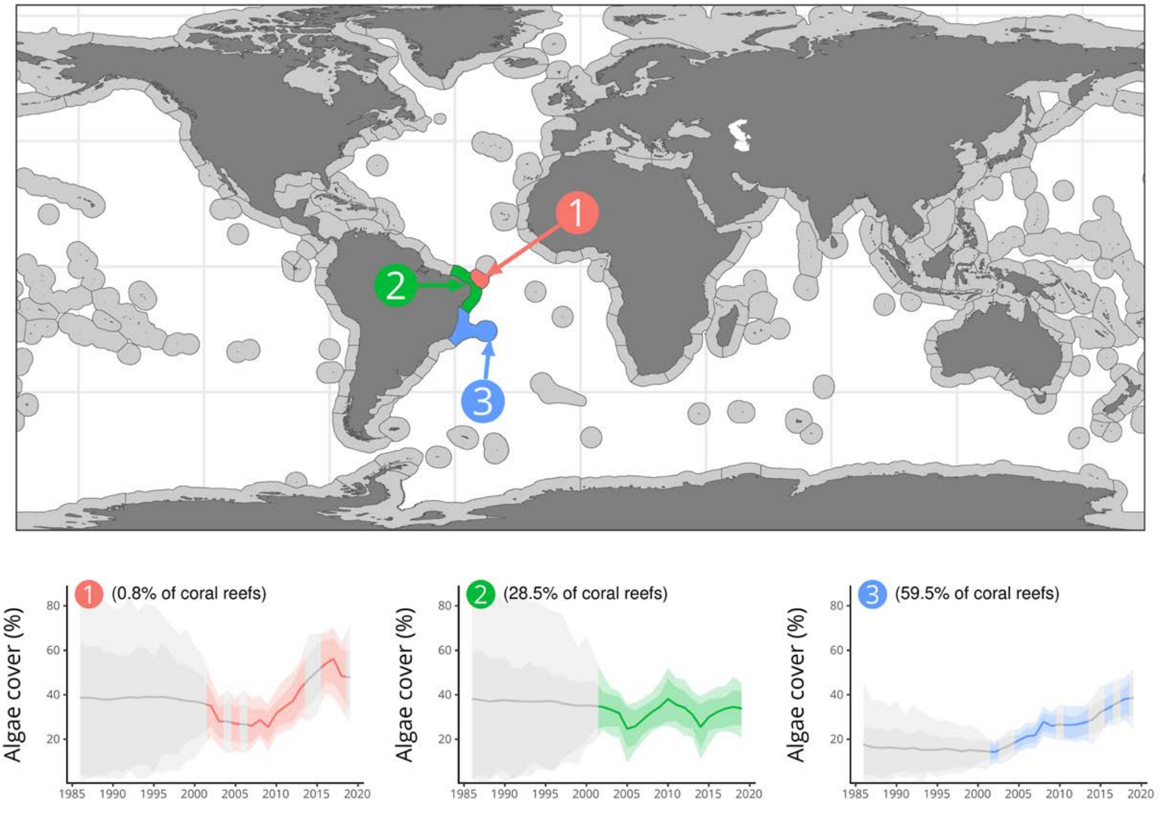

Figure 11.7. Estimated average cover of algae within each subregion comprising the Brazil region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available. The proportion of all coral reefs in the Brazil region within each subregion is indicated by the % of coral reefs.

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