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Global Coral Reef Monitoring Network

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International Coral Reef Initiative

Australian Government

Australian Institute of Marine Science

Status of Coral Reefs of the World: 2020

Chapter 6. Status and trends of coral reefs of the South Asia region

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Chapter 6.

Status and trends of coral reefs of the South Asia region

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1. Geographic information and context

Key numbers:

- Total area of coral reefs: 10,949 km^2
- Proportion of the world's coral reefs: 4.22%
- Number of countries with coral reefs: 7
- Number of Marine Ecoregions of the World (MEOW) ecoregions: 6

Regional Context:

The South Asia region is one of the smaller GCRMN regions in terms of area of coral reefs, accounting for only 4.2 % (10,949 km^2) of global area of coral reefs. These reefs are distributed among six sovereign countries (Bangladesh, India, Maldives, Myanmar, Pakistan and Sri Lanka) and the Chagos Archipelago. Much of the reef area is concentrated along the more than 2,000 km long Lakshadweep-Maldives-Chagos Ridge, which accounts for around 75% of the total reef area in the region. Other significant reef systems are found in the Gulf of Mannar, and around parts of Sri Lanka. Reef development is poor along mainland India, Pakistan and Bangladesh.

Despite its relatively small area, South Asia contains a wide variety of coral reef habitats that vary significantly in reef structure, biodiversity, proximity to continents, and anthropogenic impacts. Many reefs face severe human pressure from overfishing and destructive fishing, coastal development, land-based agricultural runoff, and increased sedimentation. In general, reefs around atolls and offshore islands are subject to less anthropogenic pressure and remain in better condition than those around the South Asian mainland and coastal islands. Climate change has increased vulnerability of both coral reefs and coastal communities to the impacts of higher temperatures and extreme weather events. Sea level rise is a major threat to island communities in the Maldives and Lakshadweep Islands.

Coastal communities throughout the region are directly dependent on reef resources. Coral reefs play a significant role in national economies, and in supporting livelihoods through fisheries and tourism, particularly in Maldives, India and Sri Lanka. Marine fishery resources are the main source of protein for coastal communities, accounting for over 66% of protein consumed in Sri Lanka and over 90% in Lakshadweep and Maldives.

South Asia is characterized by a high population and high population densities. The total population of the region exceeds 1.8 billion, with densities ranging from 244 people per km^2 in Pakistan to more

than 1,100 people per km^2 in Maldives and Bangladesh. Despite the small number of countries, there is significant cultural, social and economic variation among states and local communities. With the exception of Maldives, poverty is widespread, especially among coastal populations. Gross Domestic Product ranges from USD15,463 in Maldives to USD1,349 in Pakistan.

The South Asia region includes six distinct ecoregions under the Marine Ecoregions of the World (MEOW) classification[1] (Tab. 6.1, Fig. 6.1) grouped into four subregions. Data from each ecoregion is reported here but does not include data from Pakistan and Bangladesh.

Table 6.1. The subregions comprising the South Asia region, the area of reef they support, and the constituent Marine Ecoregions of the World (MEOW)[1].

Subregion	Reef Area (km^2)*	Proportion of Reef Area within the South Asia Region(%)	Constituent Marine Ecoregions of the World
1	2,731	24.94	106: Chagos
2	6,372	58.2	105: Maldives
3	1,032	9.43	103: Western India 104: South India and Sri Lanka
4	813	7.43	107: Eastern India 108: Northern Bay of Bengal

*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

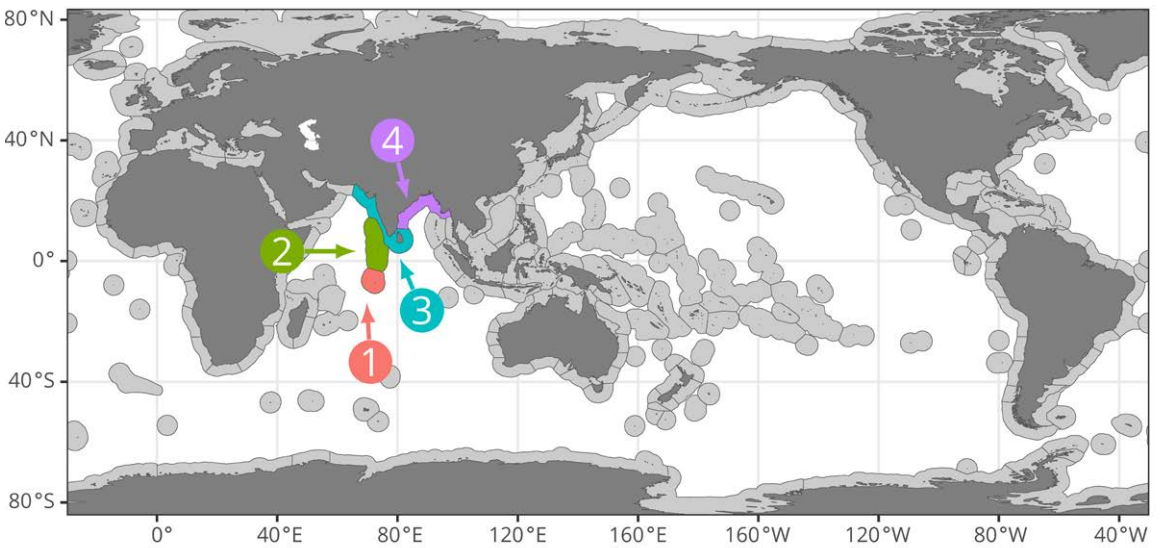

Figure 6.1. Map of each subregion comprising the South Asia region. The number ascribed to each subregion corresponds with that in Table 6.1.

[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. Summary of data contributed to this report

Key numbers:

- Number of countries from which monitoring data were used: 5 (of 7)
- Number of sites: 389
- Number of observations: 48,891
- Longest time series: 20 years

General features:

The status and trends of coral reefs in South Asia are presented below and are based on almost 49,000 observations from 389 sites distributed across five countries and territories within the South Asia region (Tab. 6.2). These data were collected primarily using transect-based methods (Fig. 6.4).

Coral reef research is relatively new in South Asia with significant constraints in capacity. This is reflected in the limited long-term monitoring data available for the region (Fig. 6.2, Fig. 6.3A). The distribution of monitoring effort over time has primarily been in response to major disturbance events. Only a small amount of monitoring data collected prior to 1998 were contributed to this analysis, with the earliest data collected from the Chagos Archipelago in 1978 (Fig. 6.3B). Widespread monitoring began in response to the 1998 global coral bleaching event, which had a significant impact on coral reefs in the region. Additional increases in the number of surveys occurred around 2005 related to the Indian Ocean tsunami. Survey intensity has continued to increase with a peak around the 2016 mass bleaching event (Fig. 6.3B). The greatest number of surveys were conducted in subregion 3 (Western India, South India, and Sri Lanka) followed by subregions 1 (Chagos) and 2 (Maldives). Few data were reported for subregion 4 (Eastern India, Northern Bay of Bengal).

Long-term monitoring data (>15 years between the first survey and the most recent survey) were reported from only nine sites, all of which were located in the Maldives (Tab. 6.2, Fig. 6.2 and 3A). The lack of long-term monitoring data is a major shortcoming in the region. More than 60% of the sites included in this analysis were surveyed in only one year (Fig. 6.3A). The South Asia region has also suffered from the lack of a coordinated data management program both nationally and regionally, resulting in poor reporting of data. The volume of data contributed to this analysis from the region may significantly under-represent the data that have been collected within the region historically.

Table 6.2. Summary statistics describing data contributed from the South Asia 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.

South Asia 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	48,891	5.04	389	3.2	9	1.53
1	5,920	0.61	160	1.32	0	0
2	5,561	0.57	136	1.12	9	1.53
3	37,315	3.85	89	0.73	0	0
4	95	0.01	4	0.03	0	0

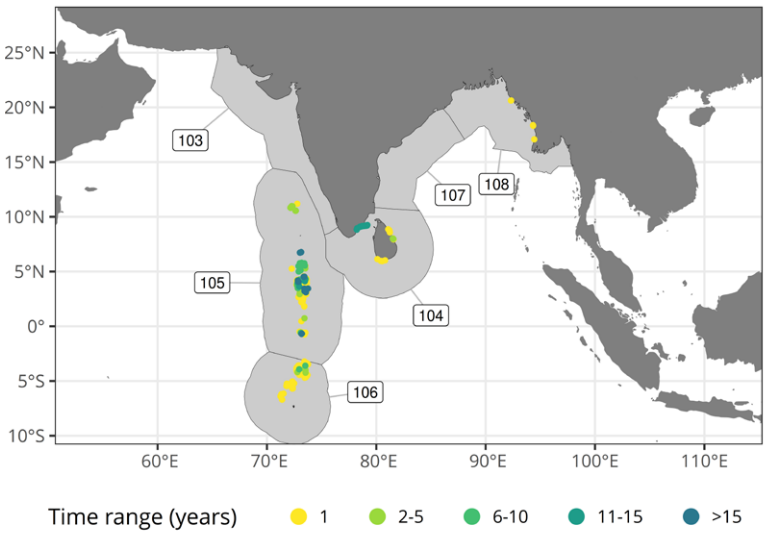

Figure 6.2. The distribution and duration of monitoring at sites across the South Asia region. The colours of dots represent the time span between the first survey and the most recent survey at each site. Numbers refer to the MEOW ecoregions listed in Table 6.1.

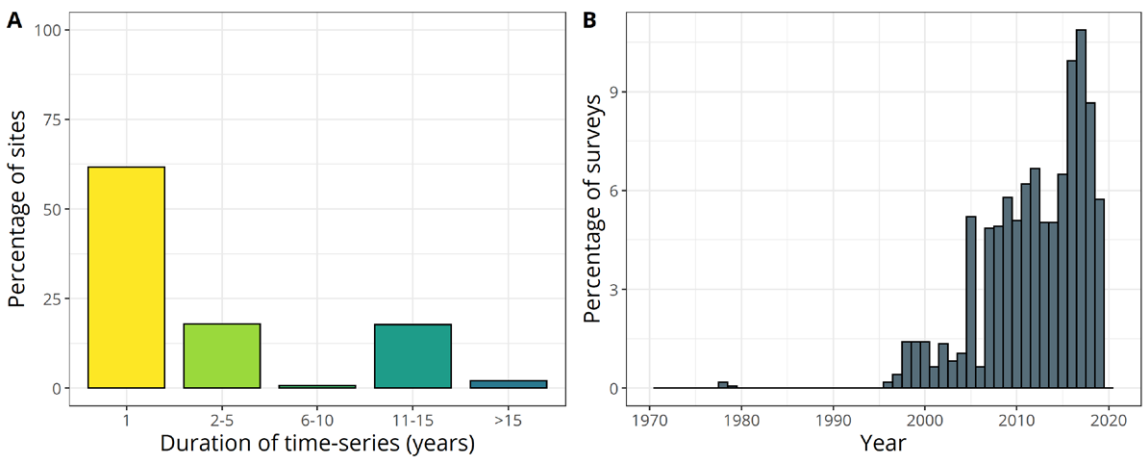

Figure 6.3. The proportion of sites in the South Asia region within each category describing the time span between the first and most recent surveys (A), and the proportion of the total number of surveys conducted in each year (B).The total number of surveys is 1,635.

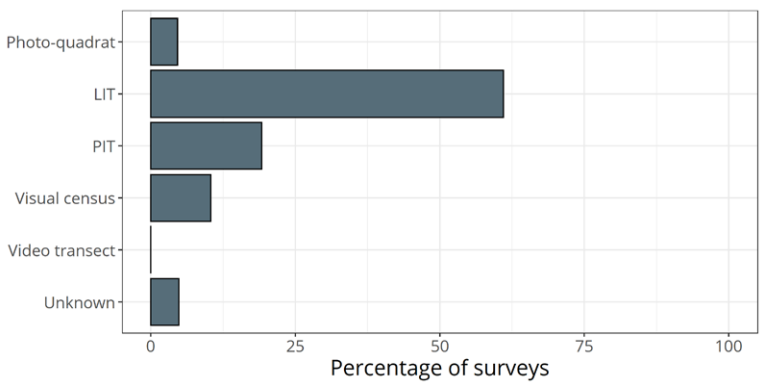

Figure 6.4. The proportion of the total number of surveys conducted in the South Asia region using each survey method. PIT: Point Intercept Transect; LIT: Line Intercept Transect.

3. Status of coral reefs in the South Asia region

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

Overall, there was a declining trend in live hard coral cover in the region, most significantly as a result of El Niño-related coral bleaching events in 1998 and 2016 (Fig. 6.5A). Although reefs showed significant recovery between 1998 and 2010, extensive bleaching-induced mortality in 2016 and localized coral bleaching events from 2017-2019 have continued to cause declines in live hard coral cover. Although there was considerable uncertainty owing to the scarcity of data, the estimated average cover of live hard coral prior to 1998 was relatively high and stable, ranging between 38.0% and 46.4% (Fig. 6.5A). However, about 70% of the living hard coral was lost as a result of extensive coral mortality caused by the 1998 coral bleaching event, reducing the average live hard coral cover in the region to around 11.8% by 1999 (Fig. 6.5A). Some recovery was observed over the next decade as live hard coral cover increased to 39.4% by 2010 and remained relatively stable until 2016. The mass coral bleaching event in 2016 had severe impacts on reefs in the region, killing more than 42% of the living hard coral and reducing the cover of live coral to 26.3%.

The average cover of algae remained relatively low and stable at about 10% until 2008, after which there was a progressive increase to 14% by 2018 (Fig. 6.5B). While a decline in live coral cover, such as that seen during the 1998 coral bleaching event, would be expected to result in an increase in algal cover, this is not evident in the early data, although short term increases in algal cover immediately after major bleaching events may be overridden by the noticeable recovery of reefs between 1998 and 2010 (Fig. 6.5A). However, since 2015, there was an upward trend in algal cover, which corresponds with a decline in live coral cover due to coral bleaching. The increased monitoring and reporting of data was a likely contributor to this trend being more visible.

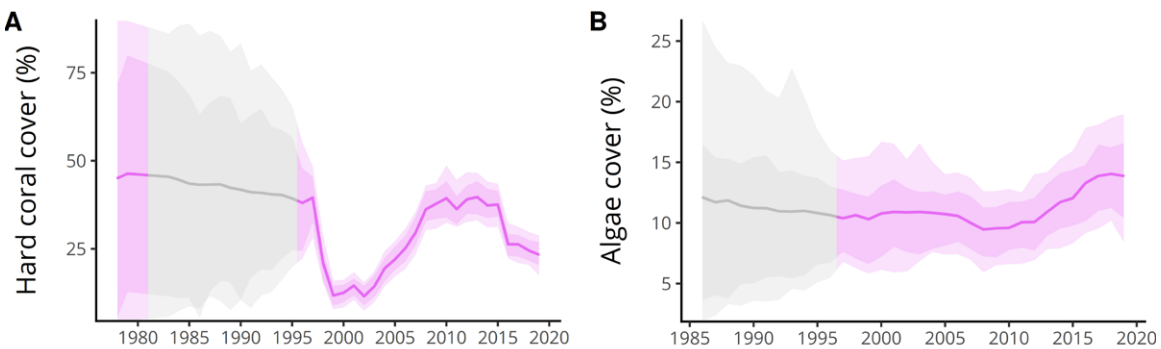

Figure 6.5. Estimated regional average cover of live hard coral (A) and algae (B) for the South Asia region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available.

When comparing the average live hard coral cover between five-year periods (2005-09, 2010-14, 2015-19), there was strong evidence (94.3%) that coral cover increased between 2005-09 and 2010-14 (4.3% on average) as reefs continued to recover from the 1998 mass coral bleaching event, but that these gains were erased by a decline in average live hard coral cover between 2010-14 and 2015-19 (Tab. 6.3). As a result, the hard coral cover declined between 2005-09 and 2015-19 by an average of 8.7%, which represented an overall loss of 34% of the living coral from the region during this period.

Table 6.3. Probability and magnitude of mean absolute and relative change in the percent cover of live hard coral in the South Asia 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	94	4.3	21.2
2010-14 - 2015-19	100	-12.9	-45.2
2005-09 - 2015-19	100	-8.7	-34.0

Similar comparison of the average cover of algae between five-year periods (2005-09, 2010-14, 2015-29) showed weak evidence (79% probability) of an increase in algal cover between 2005-09 and 2010-14, but much stronger evidence (95% probability) of a larger increase between 2010-14 and 2015-19 (Tab. 6.4). These results strongly indicate (99% probability) that there was more algae on South Asian coral reefs in 2015-19 compared with 2005-09. On average, there was 51% more algae, with almost two-thirds of this increase occurring between 2010-14 and 2015-19 (Tab. 6.4).

Table 6.4. Probability and magnitude of mean absolute and relative change in the percent cover of algae in the South Asia 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	79	1.1	14.8
2010-14 - 2015-19	95	2.8	32.8
2005-09 - 2015-19	99	3.9	50.7

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

Coral bleaching has been the major driver of coral loss in the South Asia region. The first major coral bleaching event occurred in 1998 resulting in extensive loss of live coral cover across the region (Fig. 6.5A). Some shallow reefs in Maldives, Lakshadweep and Sri Lanka suffered coral mortality exceeding 90%, with *Acropora* and *Echinopora* being the most susceptible coral genera. Smaller-scale coral bleaching was observed in 2010 (Fig. 6.5A) that had more localized impacts with significantly less coral mortality compared to the 1998 bleaching event. A second major bleaching event occurred in 2016 (Fig. 6.5A), although the coral mortality associated with the 2016 event was less than that in 1998, partly because there was less coral, but also because there were more bleaching resistant species within the coral community. A smaller bleaching event in 2019 resulted in localized yet severe coral mortality in some areas, particularly along parts of the east coast of Sri Lanka.

In addition, coastal fringing reefs along mainland India, Bangladesh, Pakistan, and Sri Lanka continue to suffer from anthropogenic stresses such as overfishing, destructive fishing, coastal development, pollution and sedimentation. Some reefs have shown little to no recovery since the 1998 coral bleaching event due to chronic stress, while more healthy reefs continue to experience loss of coral cover, fish biomass and diversity as a result of human impacts. Reefs around offshore island groups such as the atolls along the Lakshadweep-Maldives-Chagos Ridge have significantly less anthropogenic pressure. Many of these reefs have restricted access or have been declared marine protected areas (MPAs), with the largest being the Chagos MPA. Coral bleaching remains the primary threat to these reefs.

- Changes in resilience of coral reefs within the GCRMN South Asia region

Repetitive coral bleaching events and natural disturbances may have changed long-term disturbance-recovery patterns to the point that many reefs are not recovering completely from one disturbance before experiencing another. Smaller, localized bleaching events may have more significant impacts if they follow a larger bleaching event as a result of a short window of recovery for reefs. The problem is more acute on coastal reefs that are subjected to high levels of anthropogenic stress, and where long-term pressure has decreased resilience to natural and climate-related disturbances. Reef recovery is highly variable with better recovery on atolls along the Lakshadweep-Maldives-Chagos Ridge. Nearshore reefs that experience higher rates of overfishing and pollution have shown low to no recovery since the 1998 coral bleaching event. In Sri Lanka, the erosion of reef structures from waves associated with seasonal storms has led to the loss of stable hard substrate, inhibiting recruitment and reef recovery. As a result, there has been a continual decline in hard coral cover across many sites. Of the 30 sampling units in the South Asia region 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%, 28 (93%) had not recovered to at least 90% of their pre-disturbance hard coral cover (Tab. 6.5). Among these sampling units, the average decline in hard coral cover between the first survey and the most recent survey was almost 20.8%, representing a loss of 55.1% of the existing hard coral. The average maximum absolute decline in hard coral cover was 27.2%, representing a loss of 65.6% of the hard coral within these sampling units (Tab. 6.5).

Table 6.5.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
30	28	93.33	27.22	65.62	20.80	55.06

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

There was significant variation in the trends in live hard coral cover in different subregions within the South Asia region (Fig. 6.6). Trends in subregions 1 (Chagos) and 2 (Maldives) were primarily responsible for the overall regional trend in South Asia on account of supporting more than 80% of the coral reefs in the region. These subregions showed a significant decrease in live coral cover after the 1998 coral bleaching event, followed by a period of recovery until 2015 before another decline in live coral cover after the 2016 coral bleaching event. The estimated live coral cover for subregion 3 (Western India, South India, and Sri Lanka) showed a gradual decline from 2000 to 2015, and a significant decline following the 2016 coral bleaching event (Fig. 6.6). Unfortunately, the analysis does not capture the impact of the 1998 coral bleaching event and any subsequent reef recovery because the earliest data contributed from this subregion were collected in 2003. However, previous GCRMN reports and published literature indicate that the subregion exhibited similar patterns to subregions 1 and 2, albeit with less recovery in some reef areas. Data from subregion 4 (Eastern India and the Northern Bay of Bengal) were provided for only three years making it difficult to accurately describe the trends in live hard coral cover on coral reefs in this subregion. However, analysis of those few data suggested relatively stable live hard coral cover, without evidence of significant mortality from mass coral bleaching events.

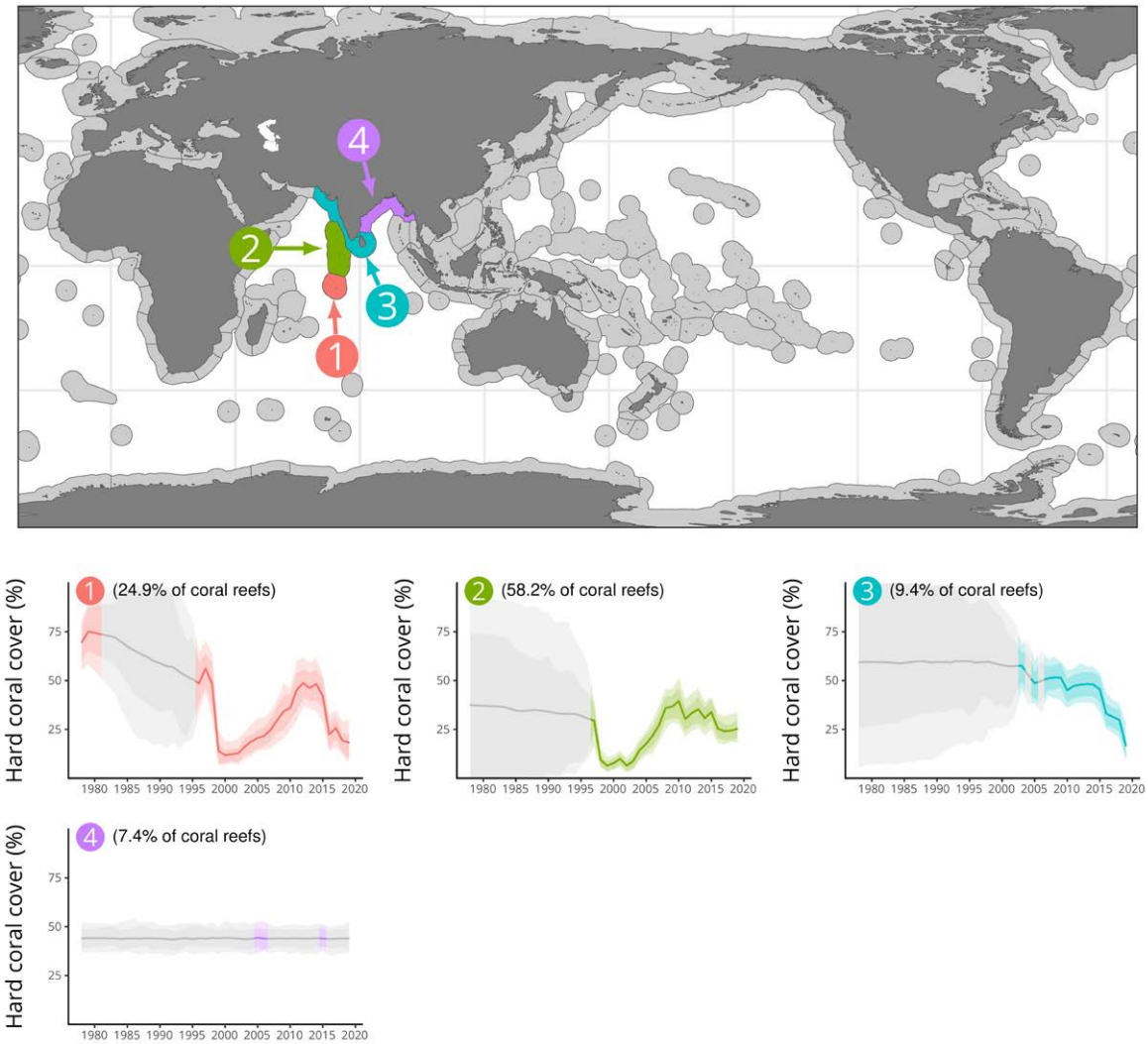

Figure 6.6. Estimated average cover of live hard coral within each subregion comprising the South Asia region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available. The proportion of all coral reefs in the South Asia region within each subregion is indicated by the % of coral reefs.

Similar to hard coral cover, trends in the percent cover of algae varied among different subregions (Fig. 6.7). For subregions 1 and 2, the increase in the average algal cover corresponds to the decrease in live hard coral cover following the 1998 and 2016 coral bleaching events. Subregion 3 showed an increase in algal cover by nearly 50% after the 2016 coral bleaching event but, owing to a lack of data, it was not possible to assess changes in algal cover following the 1998 coral bleaching event. The data contributed from subregion 4 suggest a substantial increase in average cover of algae. While it was difficult to determine the reason for this increase because data were reported from only four sites in three years, it is unlikely to have been caused by a mass coral mortality event as overall live hard coral cover has remained stable through the same period.

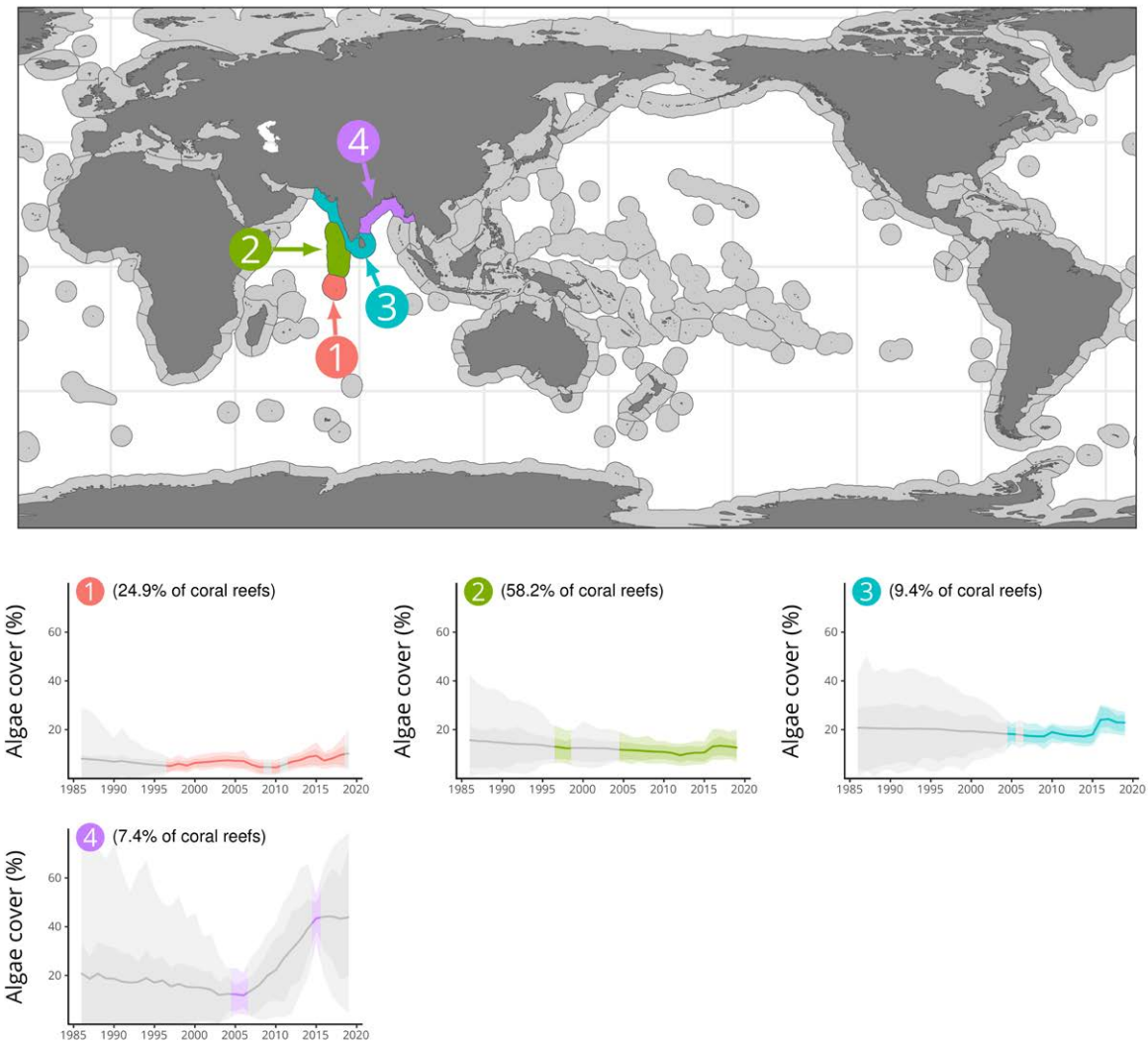

Figure 6.7. Estimated average cover of algae within each subregion comprising the South Asia region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available. The proportion of all coral reefs in the South Asia region within each subregion is indicated by the % of coral reefs.

Analysis of both live hard coral and algae within subregions highlights the issues associated with limited data from the South Asia region. Most of the data reported are from subregions 1 and 2, with very few data contributed from subregions 3 and 4. A more coordinated approach to data management including regular reporting is required to identify long-term trends and better predict resilience of coral reefs to the impacts of climate change including coral bleaching.

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