Status of Coral Reefs of the World: 2020

Chapter 10. Status and trends of coral reefs of the Eastern Tropical Pacific

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

Global Coral Reef Monitoring Network
International Coral Reef Initiative
Australian Government
Australian Institute of Marine Science
Australian Government Department of Foreign Affairs and Trade
Gouvernement Princier Principauté de Monaco
Government Offices of Sweden Ministry of the Environment and Energy
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Chapter 10.
Status and trends of coral reefs of the Eastern Tropical Pacific

Collaborators: Héctor Reyes-Bonilla, Juan José Alvarado, Franz Smith, Jorge Cortés, Fernando Zapata, Fernando Rivera, Arturo Ayala-Bocos, Alan Friedlander, Juan Pablo Quimbayo, Damien Olivier, Priscila Martínez, Ana María Millán, Tatiana Araya, Andrea Arriaga, Manuel Olán, Alejandro Pérez-Matus, Evie Wieters

1. Geographic information and context

Key statistics:

- Total area of coral reefs: 780 km^2
- Proportion of the world's coral reefs: 0.30%
- Number of countries with coral reefs: 9
- Number of Marine Ecosystems of the World (MEOW) ecoregions: 13

Regional context:

The Eastern Tropical Pacific (ETP) comprises the ocean basin extending from the Gulf of California, México to Rapa Nui, Chile, and includes areas of the continental shelf and oceanic islands. The region is bounded by subtropical gyres of the North and South Pacific and the equatorial current system of the Eastern Pacific. An additional significant oceanographic feature of the region is the eastern Pacific warm pool, located along the Central American shelf[1]. The oceanographic dynamics of the region are strongly influenced by low-latitude trade winds, topography (i.e. shelf breaks), a shallow thermocline, and inter-annual climate variation associated with the El Niño-Southern Oscillation (ENSO).

These atmospheric and oceanographic conditions create a distinct environment for the development of coral reef habitats in the region, connectivity and diversity of coral species in the region[1,2]. Localised upwelling provides increased nutrients to shallow water environments, supporting enhanced local primary production. High rainfall in areas of Central America and northern South America reduces surface salinity and contributes to localised turbidity, nutrient loading, and sedimentation. The ETP is also characterised by low surface pH values, which lowers aragonite saturation values and has direct consequences for calcium carbonate mineralisation necessary for reef-building corals[3].

Inter-annual variation in oceanographic conditions associated with ENSO cycles can have dramatic effects on coral reef ecosystems in the ETP. In particular, the El Niño events of 1982-83 and 1997-98 caused extensive mortality of reef-building corals in the region. In many localities, there has been

[1] Glynn, P.W., D. P. Manzello, and I. C. Enochs. 2017. Coral Reefs of the Eastern Tropical Pacific. Persistence and Loss in a Dynamic Environment. Springer.

[2] Cortés, J. (editor). 2003. Latin American coral reefs. Elsevier, Amsterdam.

[3] Manzello, D.P, J.A. Kleypas, D.A. Budd, C.M Eakin, P.W. Glynn and C. Langdon. 2008. Poorly cemented coral reefs of the eastern tropical Pacific: Possible insights into reef development in a high-CO2 world. Proceedings of the National Academy of Sciences 105: 10450-10455.

limited recovery of coral reef structure, indicating these events can have lasting impacts on reef ecosystems for decades[4],[5],[6].

These factors have combined to form a unique biogeographic situation in the ETP, where there is limited connectivity with the Western Pacific[7]. Subregional and localised oceanographic conditions and the presence of several offshore island archipelagos also contributes to considerable isolation for some coral assemblages within the region. There are an estimated 47 zooxanthellate scleractinian coral species present in the ETP region, of which 8 are considered endemic and the remainder are shared with the central/western Pacific.

Coastal human population density varies considerably across the ETP region, where artisanal fishing and tourism provide an important economic basis for many coastal communities. There has been a steady increase in the gross domestic product (GDP) per capita in key reef-bearing countries during the past two decades, where the average GDP has doubled or tripled in countries such as Chile, Ecuador, Panama and Costa Rica.

The ETP is comprised of 13 Marine Ecoregions of the World[8] (MEOW)(Tab. 10.1, Fig. 10.1), which were grouped into five subregions for the analyses underpinning this report (Tab. 10.1). Subregion 1 combines MEOW ecoregions in the vicinity of the Gulf of California. Subregion 2 is formed by the ecoregions extending along the coast of tropical Mexico and Central America. Subregion 3 includes the Panama Bight and coastal Colombia and Ecuador. Subregion 4 includes the offshore islands of Coco Island and the Galápagos Islands and subregion 5 includes the offshore islands of the Revillagigedo Archipelago and Clipperton Atoll, (Tab.1, Fig. 10.1). This designation captures major variations in north-south variation across the region as well as distinguishing coastal and offshore ecosystems.

Coral reef ecosystems of the ETP region are difficult to resolve using remote sensing technology and there is no comprehensive coral reef habitat map available for the region. This means the estimated area for coral reefs in the region presented in Table 10.1 may differ from the actual area of coral reefs supported by the region.

[4] Glynn, P.W. 1988. El Niño-Southern Oscillation 1982–1983: nearshore population, community and ecosystem responses. Annual Review of Ecology and Systematics 19: 129-160.

[5] Reyes-Bonilla H (2001) Effects of the 1997-1998 El Niño-Southern Oscillation on coral communities of the Gulf of California, Mexico. Bulletin of Marine Science 69:251–266.

[6] Glynn, P.W., B. Riegl, S. Purkis, J.M. Kerr and T.B. Smith. 2015. Coral reef recovery in the Galápagos Islands: the northernmost islands (Darwin and Wenman). Coral Reefs 34: 421-436.

[7] Baums IB, Boulay JN, Polato NR, Hellberg ME. 2012. No gene flow across the Eastern Pacific Barrier in the reef-building coral Porites lobata. Molecular Ecology 21:5418–5433

[8] 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

Table 10.1. The subregions comprising the Eastern Tropical Pacific region, the area of reef they support, and the constituent Marine Ecoregions of the World (MEOW)

Subregion	Reef Area (km²)*	Proportion of Total Reef Area Within the ETP Region(%)	Constituent Marine Ecoregions of the World
1	19	2.4	060: Cortezian 061: Magdalena Transition
2	255	32.7	166: Mexican Tropical Pacific 167: Chiapas-Nicaragua 168: Nicoya
3	269	34.5	170: Panama Bight 171: Guayaquil
4	227	29.1	169: Cocos Islands 172: Northern Galapagos Islands 173: Eastern Galapagos Islands 174: Western Galapagos Islands
5	9	1.2	164: Revillagigedos 165: Clipperton

*UNEP-WCMC, WorldFish Centre, WRI, TNC (2018). Global distribution of coral reefs, compiled from multiple sources including the Millennium Coral Reef Mapping Project. Version 4.0. URL: http://data.unepwcmc.org/datasets/1

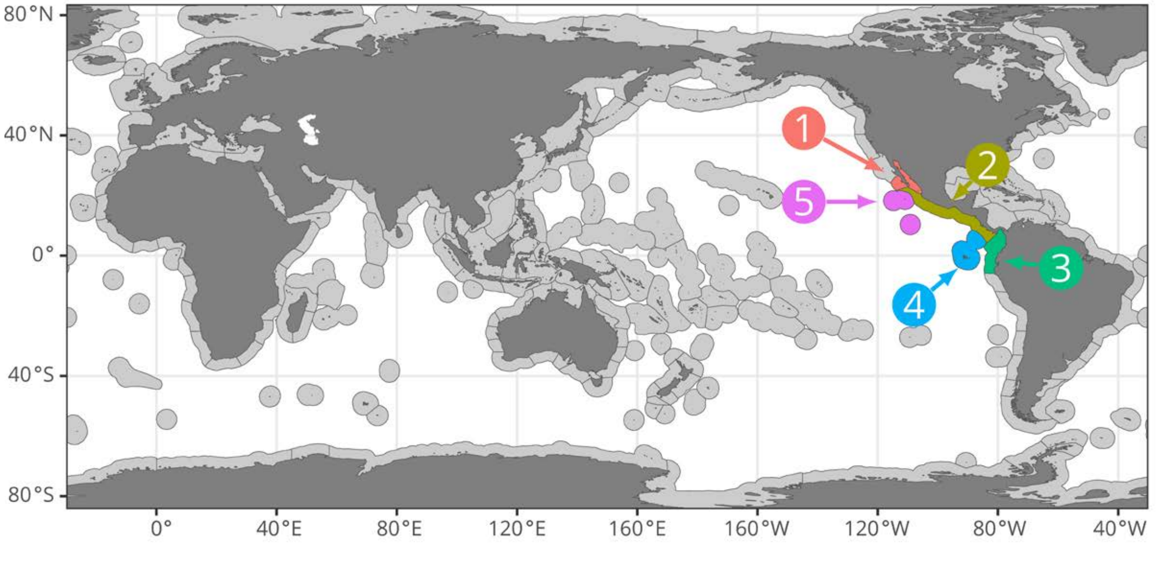

Figure 10.1. Map of each subregion comprising the Eastern Tropical Pacific region. The number ascribed to each subregion corresponds with that in Table 10.1.

2. Summary of data contributed to this report

Key numbers:

- Number of countries from which monitoring data were obtained: 8 (of 9)
- Number of sites: 352
- Number of observations: 10,627
- Longest time series: 18 years

General features:

Data were compiled for the region which extends from México to Ecuador and includes the offshore islands and archipelagos of Clipperton Atoll, Revillagigedos Islands Galápagos and Rapa Nui. The number of sites varied across territories in the region, with a total of 352 sites surveyed for the cover of coral and algae (Tab. 10.2, Fig. 10.2). The temporal resolution of the data also varied, with some time-series survey data dating back to ~18 years. The majority of sites were surveyed for shorter time periods (i.e. < 5 years, Fig. 10.3A). The number of surveys conducted increased substantially from 2005 (Fig. 10.3B). Compiled data were standardised to percent cover and taxonomic resolution was standardised to the lowest level possible (i.e. in most cases at the level of Genus or Family for corals and functional group for algae).

Table 10.2. Summary statistics describing data contributed from the Eastern Tropical Pacific 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.

Eastern Tropical Pacific 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	10,627	1.1	352	2.89	6	1.02
1	5,722	0.59	131	1.08	0	0
2	3,388	0.35	147	1.21	3	0.51
3	982	0.1	50	0.41	2	0.34
4	535	0.06	24	0.2	1	0.17
5	0	0	0	0	0	0

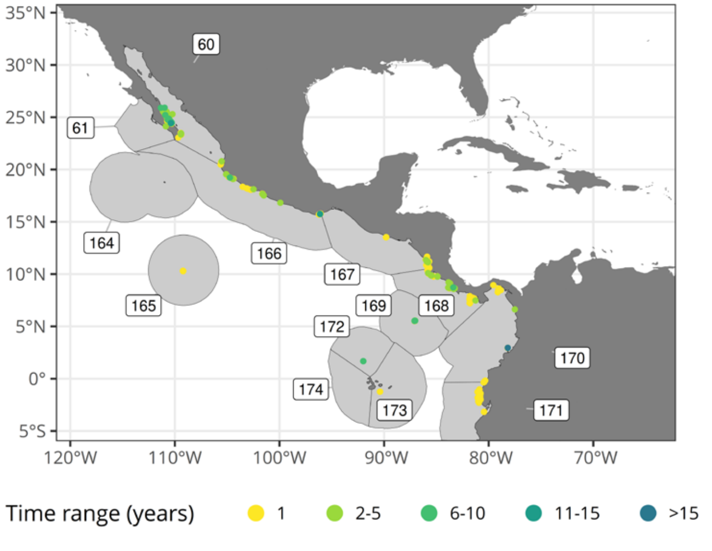

Figure 10.2. The distribution and duration of monitoring at sites across the Eastern Tropical Pacific region. The colours of dots represent the time span between the first survey and the most recent survey at each site. Numbers refer to the MEOW ecoregions listed in Table 10.1.

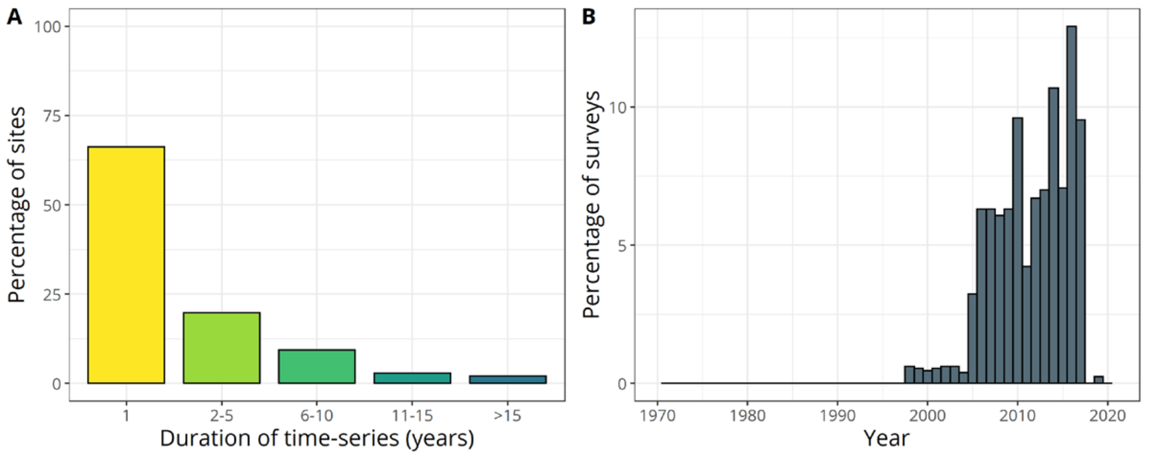

Figure 10.3. The proportion of sites in the Eastern Tropical Pacific region within each category describing the time span between the first and most recent surveys (A), and the proportion of the total number of surveys conducted in each year (B). The number of surveys was 1,277.

3. Status of coral reefs in the Eastern Tropical Pacific region

Regional trends in the cover of live hard coral and algae

The average cover of live hard coral on coral reefs in the ETP region has declined progressively from 34.6% in 1998 to 22.4% in 2016 (Fig. 10.4A). The only deviations from this downward trajectory during that time occurred in 2000 and 2010, when small increases in coral cover were recorded. Since 2016, the cover of hard coral has been maintained around 22.8%, although data from few surveys conducted in 2018 and 2019 were made available (Fig. 10.3B).

In contrast, the average cover of algae has increased across the region from 40.9% in 1998 to 49.1% in 2019 (Fig. 10.4B). The trend in the average cover of algae was characterised by a progressive increase between 2001 and 2007, followed by a slower decline until 2015. However, dramatic increases in the cover of algae were recorded in 2016 and 2017 associated with an unusual warm period across a large areas of the region.

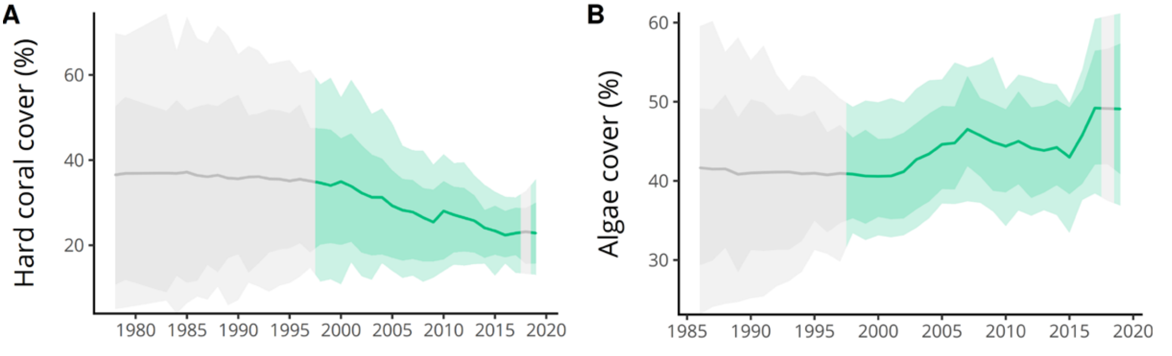

Figure 10.4. Estimated regional average cover of live hard coral (A) and algae (B) for the Eastern Tropical Pacific region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available.

Comparison of average hard coral cover between the three most recent five-year periods (2005-09, 2010-14, 2015-19) during the last 15 years shows a moderate probability (72%) of a decline in coral cover between 2005-09 and 2015-19. The decline in average coral cover was likely to be in the order of 4.4%, which equates to about 13.3% less coral on the reefs of the ETP (Tab. 10.3).

Table 10.3. Probability and magnitude of mean absolute and relative change in the percent cover of live hard coral in the Eastern Tropical Pacific 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	61	-1.9	-4.6
2010-14 - 2015-19	67	-2.5	-9.7
2005-09 - 2015-19	72	-4.4	-13.3

A similar comparison of the average cover of algae between the same five-year periods suggested a similar likelihood (72%) of an increase in algal cover between 2005-09 and 2015-19. However, the net increase was due to the high probability (83%) of an increase in algal cover in the order of 4.3 % between 2010-14 and 2015-19 after a small decline (1.2%) in algal cover between 2005-09 and 2010-14 (Tab. 10.4).

Table 10.4. Probability and magnitude of mean absolute and relative change in the percent cover of algae in the Eastern Tropical Pacific 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	68	-1.2	-4.2
2010-14 - 2015-19	83	4.3	21.2
2005-09 - 2015-19	74	3.1	15.3

- Changes in resilience of coral reefs within the Eastern Tropical Pacific region

To identify changes in the resilience of coral reefs in the ETP 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%. None of the 6 such sampling units in the ETP region recovered to at least 90% of their pre-disturbance hard coral cover (Tab. 10.5). Among those sampling units, the average decline in hard coral cover between the first survey and most recent surveys was 60.4%, which represents a loss of almost all (95.1%) the hard coral at these sites (Tab. 10.5).

Table 10.5. 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
6	6	100	63.5	96.7	60.4	95.1

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

Coastal development, eutrophication and poor land use practises in the region have also increased during the last two decades, suggesting that pressures from increased sedimentation and the alteration of coastal processes have also played a role in decreasing live coral cover and increasing algal cover. Pressure from local fisheries have also been implicated in the reduction of key coral reef grazers and predators important in controlling sea urchin populations.

The rapid population increases of invasive and noxious species has also affected coral reef ecosystems of the region. For example, blooms of noxious forms of *Caulerpa* spp., and outbreaks of crown-of-thorns starfish (*Acanthaster* spp.), and sea urchins (e.g. *Diadema* sp.) have had severe, localised impacts on reefs. The potential impacts of invasive species on coral reef processes is an emerging area of research for the area and highlights the interplay of human-derived and natural variability that determine the extent of impacts and potential actions to mitigate such impacts.

As the ETP can be strongly influenced by ENSO and other climatic events, these analyses suggest that coral reefs of the region may be more resilient to climate fluctuations than previously thought, although there has been a decline in live coral cover since the severe ENSO event of 1997-1998.

The ETP region is fortunate to have a number of large marine protected areas (MPAs), which predominantly occur around islands or in offshore areas (e.g. Coiba, Panama; Galápagos Islands) and protect coastal areas in the region. These large MPAs serve as important reference points to assess broader regional change and to better understand ecosystem recovery and resilience across coastal-offshore ecosystems.

4. Subregional trends in cover of live hard coral and algae within the Eastern Tropical Pacific region

Within the ETP region, there was a considerable degree of heterogeneity in the estimated trends in the covers of coral and algae (Fig. 10.5 & 6). For example, in the coastal subregions, there was a sharp decline following the 1997-98 ENSO event in subregion 1 and a more gradual decline across two decades in subregion 3. In contrast, little change occurred in the average cover of hard coral in subregion 2. In contrast, offshore subregions (4 & 5) showed a moderate increase in average coral cover since 2010 (Fig. 10.5), although few data were available for subregion 5 and it is difficult to generalise across the entire subregion.

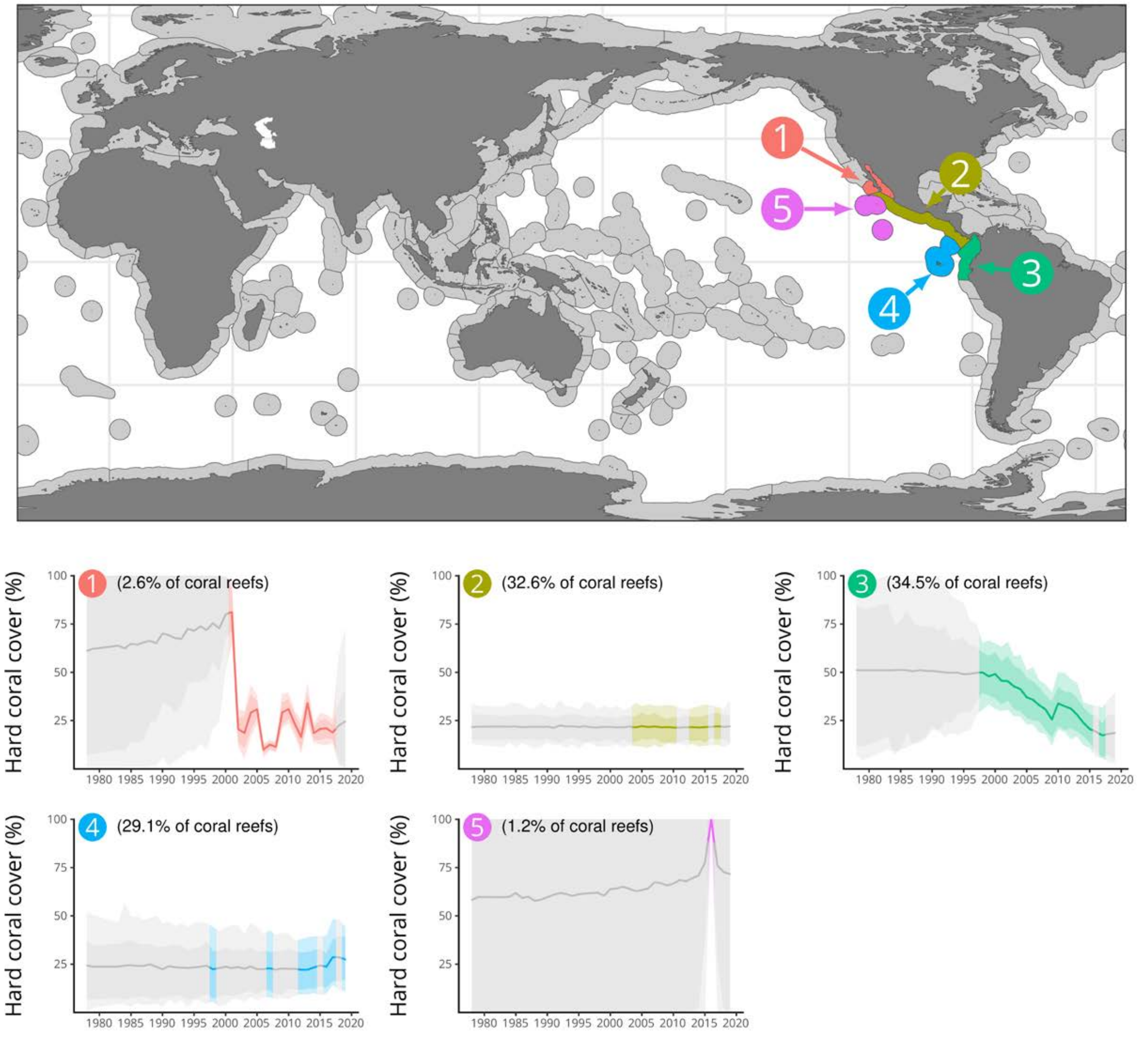

Figure 10.5. Estimated average cover of live hard coral within each subregion comprising the Eastern Tropical Pacific region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available. The proportion of all coral reefs in the Eastern Tropical Pacific region within each subregion is indicated by the % of coral reefs.

In subregion 1, there was a sharp increase in the average cover of algae after the 1997-98 ENSO event, followed by decline to 2010 and a moderate increase to 2018 (Fig. 10.6). Subregions 2 and 4 showed high (~50%) and stable trends in algal cover. In contrast, subregion 3 showed a moderate increase in algal cover from 1997 to 2007, followed by a decrease to 2016. This was followed by an relatively sharp increase in algal cover to 2018, suggesting that distinct changes have occurred recently for this subregion (Fig. 10.6). No data describing algal cover were available from subregion 5.

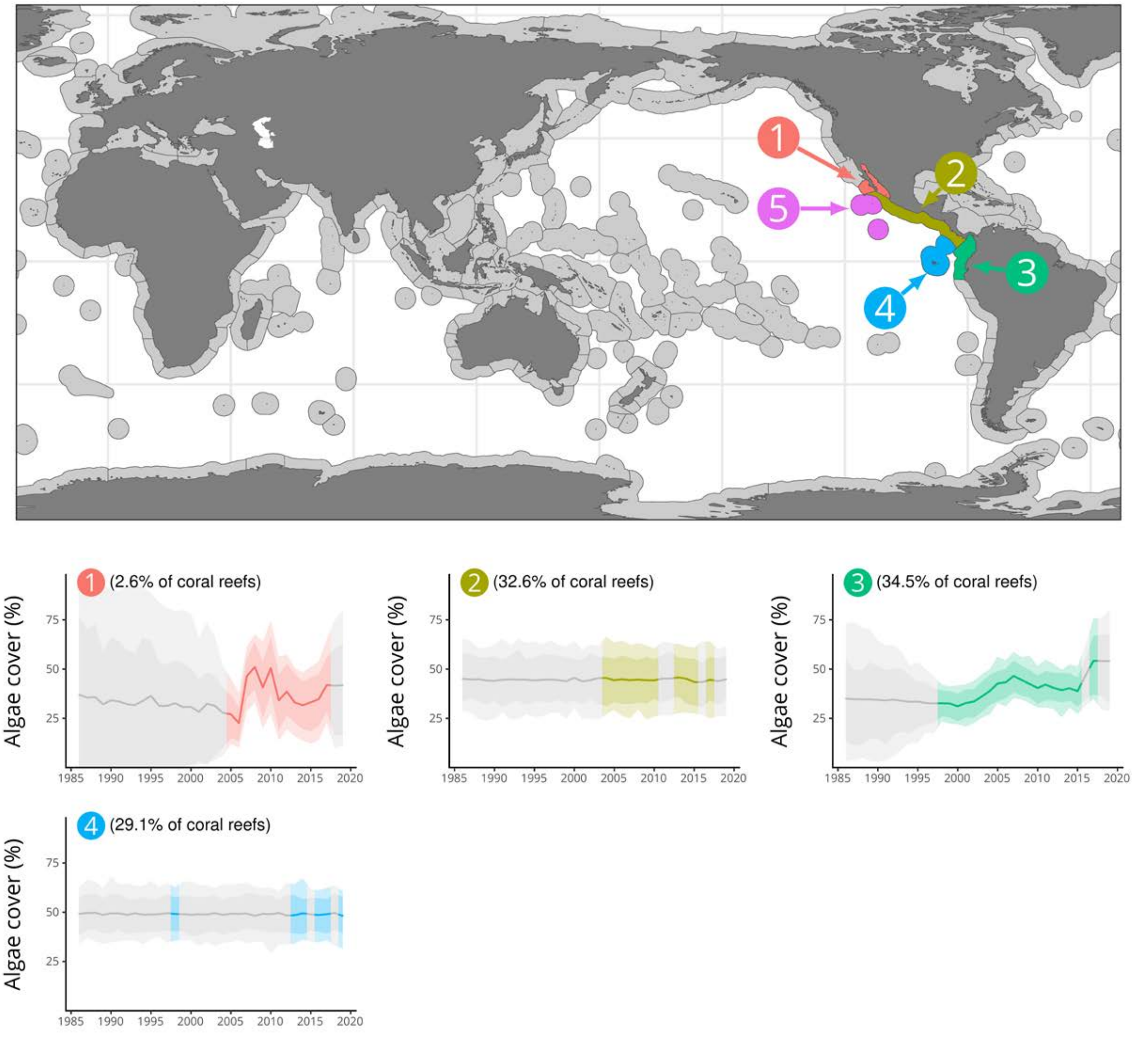

Figure 10.6. Estimated average cover of algae within each subregion comprising the Eastern Tropical Pacific region. The solid line represents the estimated mean and associated 80% (darker shade) and 95% (lighter shade) credible intervals, which represent levels of uncertainty. Grey areas represent periods during which no field data were available. The proportion of all coral reefs in the Eastern Tropical Pacific region within each subregion is indicated by the % of coral reefs. Note: no data describing the cover of algae were available for subregion 5.

Box 9.

The Allen Coral Atlas

The Allen Coral Atlas provides detailed maps of the world's coral reefs derived from high-resolution satellite images. The Atlas will provide scientists, reef managers, conservationists and countries with an unprecedented amount of data describing the location and structure of coral reefs to help monitor, conserve and restore these critical ecosystems around the world.

The Allen Coral Atlas was launched in December 2017 through a partnership established by Vulcan that now includes Planet, The University of Queensland, Arizona State University and the National Geographic Society. When established, Vulcan and its partners announced the intent to map the world's shallow coral reefs by 2021 and, once reefs were mapped, would deploy a monitoring system to alert Atlas users to changes that could indicate potential coral bleaching.

By late 2018, the Atlas team completed the first ever global photo-mosaic of the world's coral reefs derived from satellite imagery. This map illustrated the global distribution and extent of coral reefs using machine learning tools to differentiate reef area from non-reef area in a globally consistent way. As of December 2020, the Atlas features detailed maps of the Andaman Sea, eastern Africa and Madagascar, eastern Papua New Guinea and Solomon Islands, Hawaiian Islands, Northern Caribbean, Florida and the Bahamas, Southwestern Pacific, Timor and Arafura Seas, Western Indian Ocean and Western Micronesia. The team is on track to complete the global map, at unprecedented resolution, by mid-2021.

In October 2020, the Atlas, in partnership with NOAA's Coral Reef Watch, deployed a time series functionality that displays sea surface temperatures back to October 2018. Most recently, Atlas developers delivered a coral bleaching detection system for the Hawaiian Islands that uses machine learning to analyze changes in the brightness of individual pixels of satellite images over time. This new feature will be expanded globally within the next year and will enable coral scientists to identify areas potentially experiencing coral bleaching and to respond to these events.

As the Atlas matures, it will provide increasingly accurate maps of the distribution and extent of the world's coral reefs. The Atlas will be a key tool used to accurately weight the statistical models that underpin *GCRMN Status of Coral Reefs of the World* reports and to monitor and measure progress against the Convention on Biological Diversity Post-2020 Global Biodiversity Framework goals, targets and indicators. The Allen Coral Atlas will provide the maps and data to help the coral reef monitoring community, including scientists, reef managers, conservationists, countries and networks such as the GCRMN, understand the location, area and status of their coral reefs.

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