

A bad year for
Caribbean corals

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The years 1998 and 2005 were the two most damaging years for coral reefs in recorded history. They were also the world's hottest years since records began in 1880. About 16% of the world's reefs were lost to coral bleaching in the Indian Ocean and Western Pacific in 1998. Seven years on, unusually warm waters caused even worse coral bleaching, this time in the Caribbean where it was also a record year for hurricanes. Some of these hurricanes nevertheless had a silver lining: although they caused extensive damage, they also helped to save many corals by 'taking the heat off them.'

Unlike the events of 1998, the climate-related bleaching event in the Caribbean did not occur in an information vacuum. This time, there were many scientific tools available and alerts were issued to those working and managing coral reefs in the Caribbean. Thanks to the pooling of data by the Global Coral Reef Monitoring Network, US National Oceanic and Atmospheric Administration (NOAA) and Reef Check, it has been possible to follow the sequence of events leading up to coral bleaching and to document much of the damage to reefs and livelihoods in the wider Caribbean. This information has been compiled in a book on the *Status of Caribbean Coral Reefs after Bleaching and Hurricanes in 2005*. The report was launched on 4 February at UNESCO in Paris by the Global Coral Reef Monitoring Network, whose members include UNESCO's Intergovernmental Oceanographic Commission, UNEP, ReefBase, NOAA, Reef Check, the World Wildlife Fund, World Conservation Union and many other collaborators.

The Caribbean is home to 10% of the world's coral reefs. Corals bleach when the coral animal host is stressed and expels the symbiotic zooxanthellae (algae) that provide much of the energy for coral and reef growth. Although several different stresses cause bleaching, by far the most significant cause of coral bleaching in the past 25 years has been sea-surface temperatures exceeding the normal summer maxima by 1°C or 2°C for at least four weeks. This results in a build-up of toxic oxygen radicals in the algae, causing the host coral to expel the algae. This leaves the coral ghostly white and particularly susceptible to death from starvation or disease.

If conditions improve, corals will often recover, although they may experience reduced growth and skip reproduction for a season. In 2005, numerous bleached corals did eventually die.



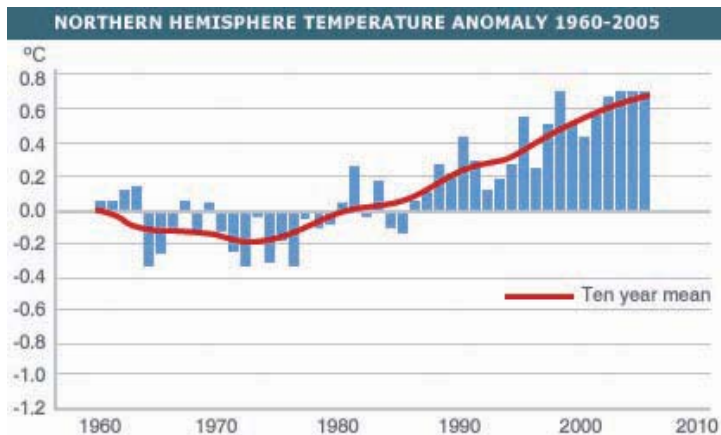
A bleached colony of *Montastraea* sp. at a depth of 10 m in Lime Cay (Jamaica) in November 2005

Many of the 13 hurricanes which passed through the Caribbean in the summer of 2005 caused considerable damage to the reefs via wave action and runoff of muddy, polluted freshwater but the effects were not all bad. The milder hurricanes helped to lower the temperature of the water by mixing deeper cooler waters into surface waters. Notably, none of the hurricanes passed through the Lesser Antilles to cool the waters where the largest HotSpot persisted.

May – In May, analysis of satellite images by NOAA showed that the waters of the Southern Caribbean were warming faster than normal. NOAA issued a regular series of information bulletins, warnings and alerts on the warming waters and developing hurricanes to coral reef managers and scientists, who then knew to examine their coral reefs for signs of bleaching.

June – The first coral bleaching in the Caribbean was reported in early June on the Islas del Rosario in northwest Colombia where waters had warmed to 30°C. These waters then cooled and the corals recovered. By late June, surface waters exceeded 30°C around Puerto Rico and up to 50% of corals had already died. There was also bleaching on the Caribbean coast of Panama, although mortality was low.

This graph from the Hadley Climate Centre in the UK shows that temperatures in the Northern Hemisphere have been much higher in the past two decades and appear to be increasing from the baseline of temperatures in 1960



July – Bleaching was reported in Belize, Mexico, Bahamas, Bermuda and the Virgin Islands. This coincided with reports of the death of large sponges in the Virgin Islands and off Cozumel in Mexico.

The unusually strong Hurricane Dennis struck Grenada, Cuba and Florida. Dennis was followed by Hurricane Emily, which briefly held the record for severity until Hurricane Katrina struck in August. Despite cooling the waters, Hurricanes Wilma and Emily caused considerable damage to coral reefs, especially in Mexico around the island of Cozumel.

Although between 25% and 45% bleaching was reported in Belize and Mexico, the regular passage of storms in 2005 dissipated the HotSpot along the Mesoamerican Reef system, preventing any significant mortality from bleaching. Lower mortality in the Mesoamerican region may be attributable to the reduced population of temperature-sensitive corals, previous bleaching and disease events having removed the more sensitive species. It appears that the more resistant species were only slightly affected. Coral cover has decreased markedly in the past 35 years, in some cases from nearly 80% to less than 20%.

August – By early August, concern was growing that bleaching would damage the reefs of Florida and the Gulf of Mexico. As the HotSpot expanded in the north, there were reports of extensive bleaching in the Florida Keys, with water temperatures around 31°C and conditions almost totally calm and sunny. In late August, extensive bleaching coincided with the warmest water ever recorded on Sombrero Key in Florida but, fortunately for these reefs, Hurricane Katrina passed through the area as a Category 1 storm at about this time, resulting in considerable cooling of the waters. Katrina would develop into the most devastating storm ever to hit the USA, causing massive damage around New Orleans.



*A 100-year colony of *Montastraea* sp. at a depth of about 3 m in Montego Bay (Jamaica) recovering from bleaching in December 2005. In the past 50 years, many Caribbean reefs have lost up to 80% of their coral cover. The World Resources Institute Reefs@Risk analysis estimates that this loss could be costing the Caribbean region US\$140–420 million annually*

Hurricane Emily is seen spinning through the Caribbean south of Jamaica on 16 July 2005 in this Terra satellite image. By now, it has developed winds of over 230 km per hour (125 knots). Tourists in the Yucatán Peninsula are being evacuated from resort areas and beaches as the hurricane approaches. It will make landfall there on 18 July, on the island of Cozumel. After crossing the Bay of Campeche, the hurricane will make its last stand in the state of Tamaulipas in northern Mexico



Source: NASA/Earthobservatory

Bleaching spread around Puerto Rico, involving all corals and coral-like animals under similar hot, calm conditions. Severe bleaching of up to 95% was being reported from several islands in the Greater Antilles (Cayman Islands, Jamaica, Cuba) and Lesser Antilles (Guadeloupe, Martinique, St Barthelemy in the French West Indies, St Maarten, Saba, St Eustatius in the northern Netherlands Antilles, and Barbados). Bleaching in the Cayman Islands was the worst ever recorded.

September – The weather was now particularly calm for two weeks. This was accompanied by extensive bleaching of corals (80%) on the south coast of Jamaica. On the north coast of Jamaica, bleaching began to subside. Sea temperatures in the US Virgin Islands reached more than 30°C at a depth of 16 m, causing bleaching to affect most coral species. More than 90% of corals bleached down to 30 m on the nearby British Virgin Islands. More extensive bleaching continued in northern Puerto Rico. By now, the bleaching footprint had expanded to include Trinidad & Tobago. Meanwhile, the Dominican Republic reported bleaching in 68% of corals. Hurricane Rita, a Category 5 storm, passed through the Gulf of Mexico to strike Texas and Louisiana.

October – By now, dangerously high sea temperatures had been bathing the Lesser Antilles for almost six months. For most of this time, the water temperatures had exceeded the normal coral bleaching thresholds. This sustained thermal stress resulted in the most severe coral bleaching and mortality ever recorded in the Lesser Antilles, with 25%–52% coral mortality in the French West Indies and the most severe bleaching event ever recorded around Barbados. Bleaching affected all coral species at all depths. In the Netherlands Antilles, there was 80% coral bleaching around the islands to the north, near the British Virgin Islands, whereas, around Bonaire and Curacao in the south, there was only minor bleaching and virtually no mortality. Further to the east, there was 66–80% bleaching of the coral cover on Tobago. On average, the accumulated Caribbean thermal stress from August to November was greater than had been experienced by these reefs over the previous 20 years combined.

A second bout of bleaching started when the HotSpot ‘followed the sun’ to Colombia, seriously affecting corals, before peaking in Venezuela in November and December. Bleaching was highly variable, with sites reporting anything from zero to 100% bleaching but the mean was closer to 25%. Fortunately, mortality on southern reefs in tropical Latin America was far lower than on reefs to the north. Meanwhile, mighty Hurricane Wilma caused massive damage in Mexico, especially around Cozumel, and smashed many corals. By November, minor bleaching was also affecting 14–25% of corals in Venezuela, Guatemala and the Dutch islands of Bonaire and Curacao.

The HotSpots continued to expand and intensify until October, after which winter conditions cooled the waters to near normal in November and December. The hurricane season ended in December when tropical storm Zeta formed and petered out in January.

Bleaching persisted to mid-2006 in the Greater and Lesser Antilles however, in Guadeloupe, Martinique, Barbados and Trinidad & Tobago, and even into 2007 in St Barthelemy. Reefs in these parts of the Antilles have

shown few signs of recovery, with between 14% and 33% of colonies still bleached.

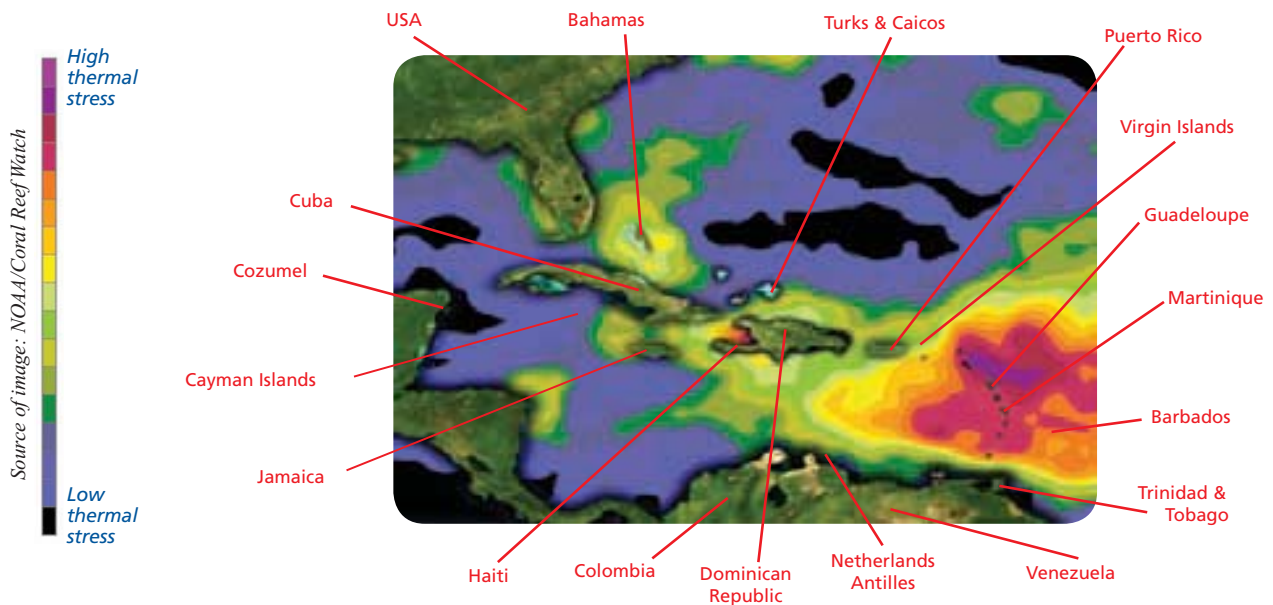
Better managed reefs will recover more quickly

Coral reef managers were unprepared for the destructive events of 1998. We now know that no form of management could have prevented the extent of coral death from a particularly severe El Niño and La Niña climate switch in 1998 which raised sea surface temperatures above known thresholds on coral reefs. The only advice the coral reef research and management community could offer was that ‘better managed reefs will recover more rapidly than those under human stresses.’

In 2006, *A Reef Manager’s Guide to Coral Bleaching* was developed to provide advice for coral reef managers faced with stresses beyond their immediate control.

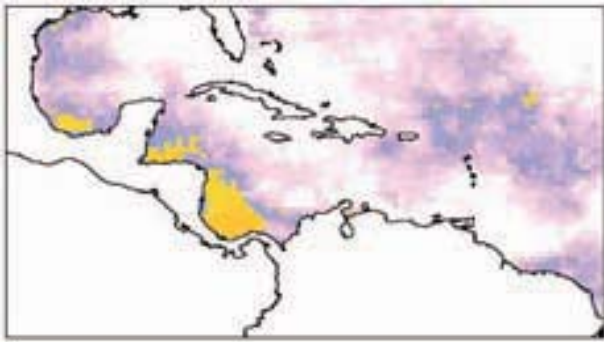
What does the future hold?

Sadly for coral reefs, all predictions from the Intergovernmental Panel on Climate Change (IPCC) reports last year

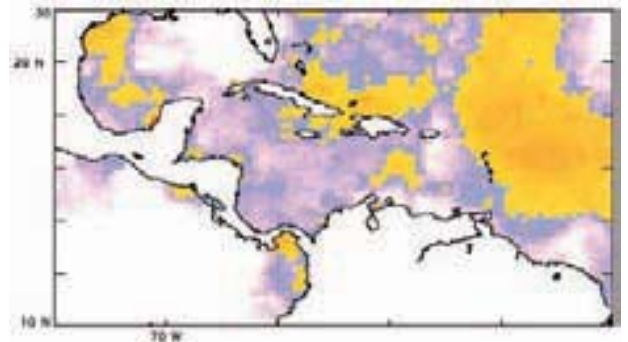


Map showing maximum level of accumulated thermal stress at each location in the Caribbean in 2005

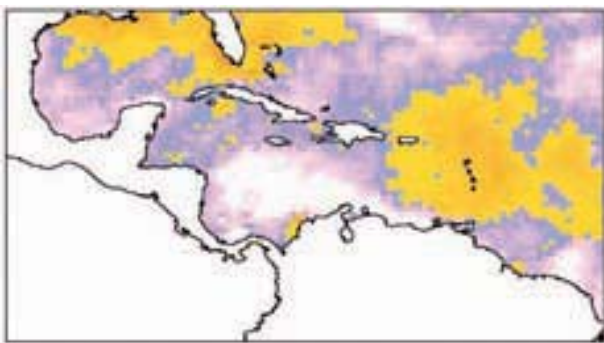
- ◆ The greatest damage occurred in the islands of the Lesser and Greater Antilles where corals were bathed in abnormally warm waters for 4–6 months. Infection rates from disease following bleaching increased from 33% to 39% in Guadeloupe and 18% to 23% in St Barthelemy; 49% of corals were infected in Martinique. Losses in the French West Indies ranged between 11% and 30%.
- ◆ There was severe bleaching in the Greater Antilles but minimal mortality in Bahamas, Bermuda, Cayman Islands, Cuba, Jamaica and Turks & Caicos; some sites in the Dominican Republic suffered up to 38% mortality.
- ◆ The greatest mortality occurred in the Virgin Islands: 52% on average due to bleaching and subsequent diseases which killed bleached colonies of Montastraea, Colpophyllia, Diploria and Porites .
- ◆ Barbados experienced the most severe bleaching event ever with 17%–20% coral mortality.
- ◆ In the northern Netherlands Antilles, there was 18% mortality in St Eustatius.
- ◆ In Trinidad & Tobago 73% of all Colpophyllia and Diploria coral colonies died; there was an increase in the prevalence of disease.
- ◆ Coral mortality was minimal on the Mesoamerican Reef system, largely because many storms cooled sea temperatures; however, Hurricanes Emily and Wilma damaged some reefs, reducing coral cover from 24% to 10%, especially around Cozumel. Coral mortality in Colombia and Venezuela was negligible.



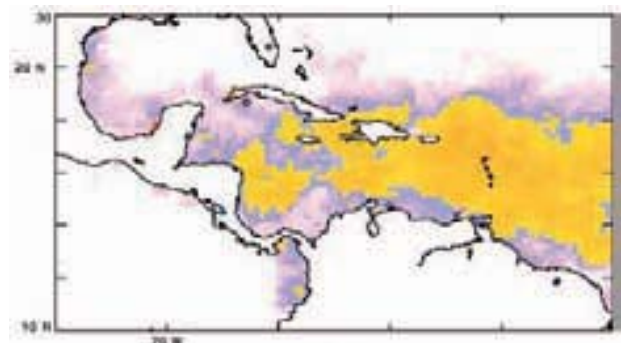
In ocean HotSpots, the water temperature exceeds normal summer levels by 1–2°C. This phenomenon becomes particularly severe if it lasts four weeks or more. This HotSpot image over central America was generated from satellite data on 16 July and distributed throughout the wider Caribbean as evidence of bleaching was being reported in Belize



By early September, two major HotSpots with sea surface temperatures 2–3°C higher than normal are covering Cuba and Hispaniola in the centre of the image and the Lesser Antilles to the right. The original HotSpot over the Gulf of Mexico and Florida has been 'blown away' by hurricanes, especially Katrina which has gone on to devastate New Orleans on 29 August



This image from 20 August shows a dramatic expansion of two HotSpots with temperatures 2–3°C in excess of the summer maximum covering large parts of the northern Caribbean, including Florida and the Flower Garden Banks in the Gulf of Mexico, and just touching Cuba. The HotSpot in the Atlantic has expanded alarmingly to cover all the islands of the Lesser Antilles. A small HotSpot is visible over Colombia



We are seeing the peak of HotSpot activity in early October with warm water covering virtually all the central and eastern Caribbean. A series of hurricanes has helped cool the waters of the northern Caribbean but no hurricanes have passed through the Lesser Antilles where the waters were warmest. Beginning in mid-October, the HotSpot will 'follow the sun' southward where it will bathe the Dutch Antilles and the northern coast of South America. By early November, the HotSpot will have virtually dissipated

indicate that the extreme warming of 2005 will not be an isolated event. With the world expected to warm by 1.8–4.0°C by the year 2100, years like 2005 are destined to become more common and more devastating for coral reefs in the wider Caribbean Sea. In addition, increasing acidity in the seawater with the absorption by the oceans of more CO₂ will slow the growth of those corals trying to recover from bleaching and other disturbances.

Hurricanes and other extreme weather events are also predicted to become more frequent and severe as the pace of climate change quickens. Warmer surface waters containing larger amounts of thermal energy will fuel stronger tropical storms. There is growing evidence that the proportion of more destructive hurricanes (Categories 4 and 5) has increased in recent decades, even as the number of tropical storms has remained stable. Stronger hurricanes will result in more severe wave damage and flooding from the land.

The bleaching in 2005 coincided with major outbreaks of coral diseases which saw extensive shrinkage in the cover of live corals throughout the Caribbean. While many corals started to recover when seawater temperatures dropped with

the onset of winter, coral diseases broke out and resulted in significant losses of coral cover, notably along the coast of Florida, in Belize, the Virgin Islands and the Lesser Antilles. The accepted explanation is that bleached corals were stressed, lacked reserve lipid supplies and were effectively starving, making them more susceptible to disease.

This is a pivotal moment for coral reefs. A dramatic reduction in greenhouse gas emissions in the next 20 years will be critical to controlling further warming and dangerously high CO₂ levels that will probably reduce the robustness of corals, thereby limiting the habitats for many other organisms living on Caribbean coral reefs and jeopardizing human livelihoods.

Clive Wilkinson and David Souter

To read State of Caribbean Coral Reefs after Bleaching and Hurricanes in 2005, download for free from: www.gcrmn.org; http://coris.noaa.gov/activities/caribbean_rpt/; or <http://www.reefbase.org/> (free registration)

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