Climate change and coral bleaching

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Coral reefs are a critical global resource, both biologically, and in socio-economic terms. They are the most diverse marine habitat, with an estimated one million different species. They are also widely used by coastal communities as a source of food and as the basis for a major tourism industry, providing both a livelihood and foreign exchange earnings for many communities and developing nations.

Coral reefs are also highly sensitive to climatic influences and appear to number among the most sensitive of all ecosystems to temperature changes, exhibiting the phenomenon known as coral bleaching when stressed by higher than normal sea temperatures.

Coral bleaching is the term used for a loss of colour in reef-building corals and the subsequent visibility of the underlying (white) skeleton. Reef-building corals are highly dependant on a symbiotic relationship with microscopic algae (a type of dinoflagellate known as zooxanthellae) which live within the coral tissues. The bleaching results from the ejection of the zooxanthellae by the coral polyps and/or by the loss of chlorophyll by the zooxanthellae themselves. This reaction of corals has been widely observed for many years: corals usually recover from bleaching but they can die in extreme cases.

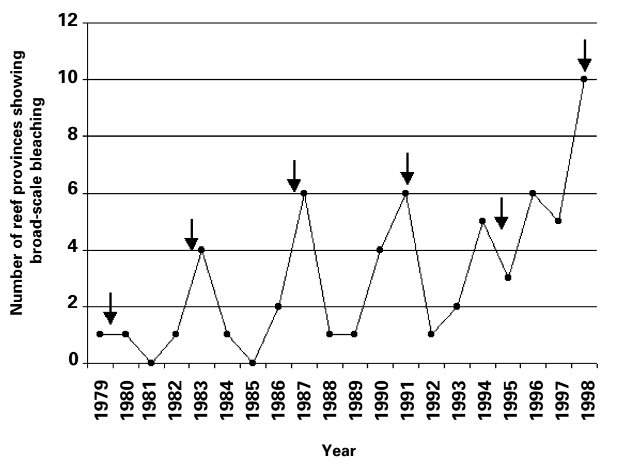
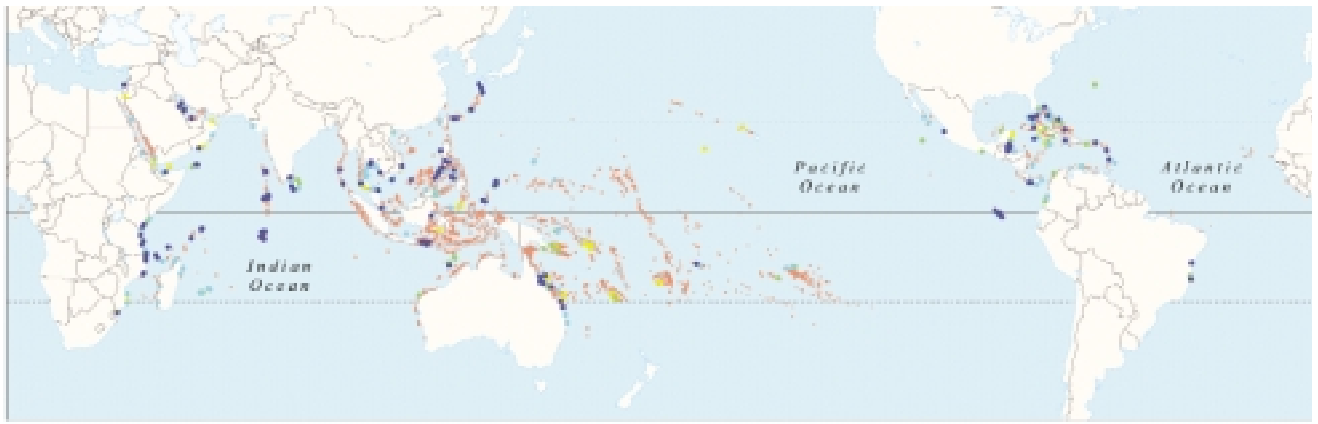
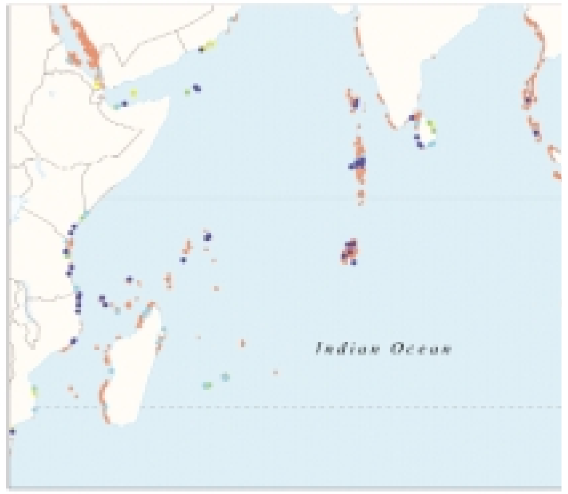


Figure 1. The number of reef provinces exhibiting moderate to severe bleaching since 1979. The arrows show the timing of the major El Niño years. Re-drawn from Hoegh-Guldberg (1999).

DISTRIBUTION OF CORAL BLEACHING EVENTS, 1998





Severity of bleaching
- 0 (low)
- 1
- 2
- 3 (high)
- Coral reef

Data sources
Bleaching events: Reefcheck; NOAA; GCRMN; CORDIO
Coral reefs: UNEP-WCMC Global Coral Reef Dataset Version 6.0

Map compiled by Corinna Ravillious.
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Figure 2. Records of coral bleaching events during 1997/98, plotted against a global map of coral reef distribution. Map shows some 550 separate data-points (with considerable overlap in some areas). This information is largely derived from expert records sent in to the NOAA/Coral Health and Monitoring Programme, together with information from the Global Coral Reef Monitoring Network and the global surveys conducted by Reefcheck. Intensity of bleaching has been classified into a semi-quantitative three-point scale of intensity. Records of 'zero bleaching' scoring a zero are marked in yellow. The global spread of this event is immediately apparent, as is the high intensity of the event on Indian Ocean reefs (detail right).

Bleaching is caused by various types of stress, including temperature extremes, pollution and exposure to air. It is temperature related stresses, however, which have been most widely reported, and which are of particular concern in relation to climate change. On any particular coral reef, the normal range of sea temperatures throughout the year is narrow – usually within 4°C – though the range of temperatures tolerated by reef-building corals world-wide is much wider (16–36°C). It would appear that corals in individual regions and localities have become highly adapted to these narrow temperature regimes. Studies have shown that temperatures of only 1–2°C above the normal range (threshold temperatures) for a few weeks are sufficient to drive a 'mass-bleaching' event (where a significant proportion of corals across the reef are bleached).

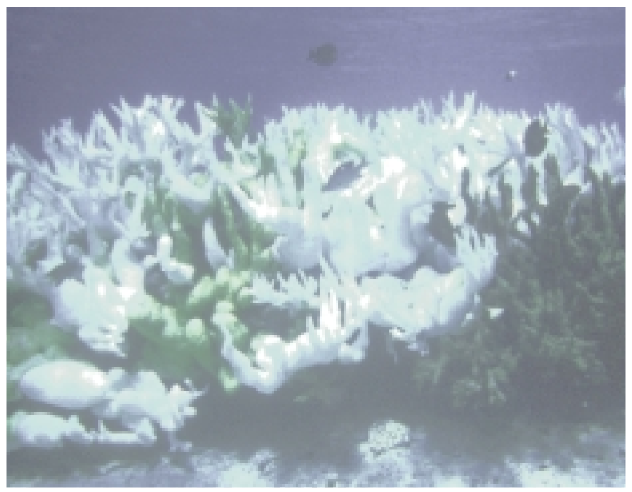
Reports of coral bleaching have increased greatly since 1979, with all records of mass-bleaching occurring after this date. The number of coral reef provinces (geographic divisions) in which mass bleaching has been reported varies widely between years, but shows a close correlation with El Niño events, as shown in Figure 1. The most significant mass-bleaching event to date was associated with the 1997–1998 El Niño, when there were records from all 10 reef provinces. Data have been compiled at the UNEP World Conservation Monitoring Centre for over 500 independent reports of bleaching during this period, and have been broadly classified based on the extent of impact. These data are presented in Figure 2. In certain areas, most notably the central Indian Ocean, this event was followed by mass-mortality, where up to 90% of all corals died over thousands of square kilometres, including virtually all reefs in the Maldives, Chagos Archipelago and Seychelles. Although new coral growth has been observed in most of these areas, full recovery from such an event will take many years or decades, while there is some concern that mortality on such a massive scale could lead to local disappearance of certain species, driving a loss in diversity and changes in community structure.

Although there are no clear records of mass-bleaching events prior to 1979, it is possible that such events could be rare but recurrent phenomena that reefs have recovered from in the past. However, the extent of coral bleaching observed during recent El Niños provides a clear indication of the wider long-term impacts of rising sea surface temperatures. Although such events are largely driven by El Niños at the present time, most climate models predict that the threshold temperatures which currently drive mass-bleaching events will be reached on an annual basis in 30–50 years.

At both the regional and local scale, certain corals have adapted to warmer, or more variable, temperature regimes. These include some of the same species which have been observed to be highly sensitive to temperature variations in other areas. Such adaptation is clearly seen in the reefs of the Arabian Gulf, where temperatures fluctuate over relatively wide extremes every year. Largely un-quantified observations in the central Indian Ocean in 1998 showed similar local-scale survival of corals in reef flat and lagoon areas. These are likely to be subject to more extreme temperatures on a regular basis, from the reduced water circulation and exposure to solar insolation and/or cold conditions in these areas. It remains to be seen whether coral larvae from these corals can recolonise reefs where more sensitive corals have died, or whether there is indeed sufficient genetic resilience within these species to adapt to the continuing increases in temperatures predicted under current models.

Further concerns compound the problems from rising sea surface temperatures. Corals may be placed under additional stress by the projected increases in atmospheric CO_2 concentration. It is believed that the concentrations of aragonite in surface waters will be reduced by such increases. Aragonite is an important component of the coral skeleton, and lower concentrations will reduce calcification rates and skeletal strength. This may lead to reduced rates of reef growth and weaker skeletal structures. All reef development is the result of coral growth out-pacing natural processes of erosion, from bioeroding organisms and also physical processes such as storms. Slower coral growth rates and weaker skeletal structures may shift the balance of many reefs from that of gradually accreting structures to that of gradually eroding structures, and this change will be further compounded by increasing rates of sea-level rise.

The 1997–1998 mass-bleaching event is providing a critical model of potential future impacts of climate change on coral reefs globally. Mass-mortalities were largely unpredicted and the wider ecosystem impacts, together with the potential for recovery and adaptation remain largely unknown.



Bleached coral, including darker patches which have recently died. Southern Seychelles, April 1998.
Photo: Mark Spalding.

Further reading

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