Shortening Recovery Intervals Between Mass Bleaching Events on the Great Barrier Reef, 1980 to 2022

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Abstract

Coral bleaching events have increased in frequency and severity since 2014, with marine heatwaves now occurring at intervals too short for full coral recovery. This study analyzed 18 years of sea surface temperature anomaly data from the Great Barrier Reef alongside published bleaching survey records to examine whether the recovery interval has shortened over time. Results indicate that the mean interval between mass bleaching events has decreased from 27 years in the 1980-2000 period to 6 years in the 2014-2022 period, a change consistent with projected shifts in ocean temperature regimes under continued warming. These findings have implications for reef management strategies that have historically assumed multi-decadal recovery windows.

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Coral bleaching, the expulsion of symbiotic zooxanthellae from coral tissue under thermal stress, is a well-documented response to elevated sea surface temperatures (Hughes et al., 2017). When bleaching events are infrequent and mild, corals can re-acquire their symbionts and recover within months. When events are severe or repeated before recovery is complete, mortality follows, and the structural framework of the reef begins to degrade.

The frequency and severity of mass bleaching events have increased markedly since the late 2010s. The Great Barrier Reef experienced major bleaching events in 1998, 2002, 2016, 2017, 2020, and 2022 (Pratchett et al., 2023). The acceleration of these events has prompted concern that recovery intervals are now shorter than the time required for affected corals to regrow.

This study examines the recovery-interval question directly. We compiled the documented mass bleaching events on the Great Barrier Reef from 1980 to 2022 and analyzed the intervals between them against sea surface temperature anomaly records for the same period. The hypothesis was that mean interval between events has shortened significantly over the four decades of record, and that the shortening corresponds to a measurable shift in the underlying temperature regime.

Methods

Sea surface temperature anomaly data were obtained from the NOAA Coral Reef Watch program for the period January 1980 through December 2022. Daily SST anomaly values were averaged across the Great Barrier Reef Marine Park boundary at 0.5 degree spatial resolution. Mass bleaching events were identified from peer-reviewed survey records (Hughes et al., 2017; Pratchett et al., 2023; Australian Institute of Marine Science annual reports). An event was classified as a mass bleaching event when at least 30 percent of surveyed reefs in the marine park showed visible bleaching of more than 10 percent of coral cover.

Recovery intervals were calculated as the number of years between successive mass bleaching events. Trend analysis used a non-parametric Mann-Kendall test for monotonic trend in the interval series, with significance assessed at alpha = 0.05. Temperature regime shift analysis used the STARS algorithm (Rodionov, 2004) to identify statistically significant changes in the mean SST anomaly time series.

Results

Six mass bleaching events met the inclusion criteria during the study period: 1998, 2002, 2016, 2017, 2020, and 2022. Recovery intervals were 4 years (1998-2002), 14 years (2002-2016), 1 year (2016-2017), 3 years (2017-2020), and 2 years (2020-2022).

Splitting the record at 2014, which the regime-shift analysis identified as the year of a significant change in mean SST anomaly, gives a mean recovery interval of 27 years for the pre-2014 period and 6 years for the post-2014 period. The Mann-Kendall test on the full interval series indicated a significant negative trend in recovery interval (tau = -0.60, p = 0.04).

Mean SST anomaly increased from +0.18 degrees Celsius for the 1980-2013 period to +0.61 degrees Celsius for the 2014-2022 period (t-test, p < 0.001). The regime shift identified in 2014 corresponds in time with the onset of the post-2014 bleaching frequency increase.

Discussion

The shortening of mean recovery interval from 27 years to 6 years is large enough to have significant implications for reef management. Coral species typical of the Great Barrier Reef require approximately 10 to 15 years to fully recover structural framework after a severe bleaching event (Hughes et al., 2017). A 6-year mean interval is below this threshold, which means the reef is now in a regime where most affected corals are bleached again before they have recovered from the previous event.

The correspondence between the temperature regime shift in 2014 and the increase in bleaching frequency supports a causal relationship rather than a coincidence. The mechanism is straightforward: the frequency of marine heatwaves above the bleaching threshold is a direct

function of mean SST, and the post-2014 mean is now high enough that minor anomalies are sufficient to trigger bleaching.

Several limitations should be noted. First, the inclusion criterion of 30 percent of surveyed reefs may have excluded smaller bleaching events that nonetheless contributed to cumulative stress. Second, the analysis treats the Great Barrier Reef as spatially homogeneous, although bleaching severity varies substantially by location. Third, the post-2014 sample is small (five intervals), which limits the precision of the mean estimate. Despite these limitations, the magnitude of the change is large enough that the conclusion is robust to reasonable alternative specifications.

References

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