Iconic coral reef degraded despite substantial protection

Nancy Knowlton[1]

National Museum of Natural History, Smithsonian Institution, Washington, DC 20013 and Center for Marine Biodiversity and Conservation, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093

The largest barrier reef in the world, Australia's Great Barrier Reef (GBR), extends for over 2,300 km and encompasses nearly 3,000 individual reef formations. An ecosystem of extraordinary diversity and beauty (Fig. 1*A*), it is a World Heritage Site that brings substantial resources to the Australian economy, including over 50,000 full-time jobs and A$5.5 billion annually (1). It is also widely considered the gold standard for coral reef management. Thus, the documentation by De'ath et al. (2) in PNAS that the substantial efforts by Australia to protect the GBR may not be adequate is cause for considerable alarm.

Their research, based on 2,258 surveys of 214 sites, documents an extraordinary decline of over half the cover of living coral on the reef, from 28.0% to 13.8% between 1985 and 2012. This amounts to a net loss rate of 0.53% per year for the entire interval, but recent losses are even higher, averaging 1.45% annually since 2006. Outbreaks by the voracious coral-eating crown-of-thorns seastar (Figs. 1 *B* and *C*), tropical cyclones (Fig. 1*D*), and coral bleaching associated with extreme warm water events were responsible for 42%, 48%, and 10% of the overall coral mortality, respectively. In this regard, the findings of decline are even more alarming because missing from the list of sources of mortality are many of the syndromes, such as massive overgrowth by algae and disease, that have caused such catastrophic losses in the Caribbean (3). Moreover, the total loss is almost certainly greater, because De'ath et al. (2) note it is likely that coral cover exceeded 28% before 1985 (e.g., Fig. 1*A*).

This is not the first problematic report card the GBR has received; a meta-analysis of coral cover on Indo-Pacific reefs suggested that those in the GBR were not strikingly better off than others in the region (4). Nevertheless, this paper comes as somewhat of a surprise because earlier reports suggested that restrictions on fishing were reducing crown-of-thorns outbreaks (1) and that coral cover was holding steady in 23 of 29 subregions of the GBR, with a much smaller overall decline being reported just last year (5). The difference in results between these two studies (Hugh Sweatman was an author on both) is argued to be due to the use of datasets that ended in 2005 in the more encouraging earlier study, before the onset of increased mortality rates.

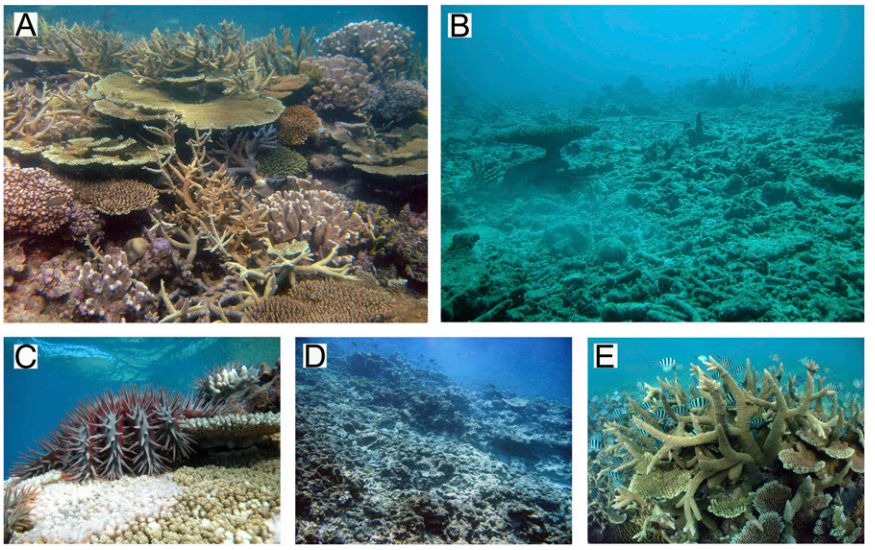

Fig. 1. GBR. (*A*) High coral cover is typical of the far northern GBR, where disturbances by cyclones and crown-of-thorns starfish are infrequent. (*B*) Repeated outbreaks by the coral-eating crown-of-thorns seastars have devastated reefs like that shown here. (*C*) Crown-of-thorns seastars feed on coral. (*D*) Tropical cyclones are also a major cause of recent coral mortality, as illustrated by a reef seen a few months after it was hit by a category 4 cyclone. (*E*) Structures provided by reef-building corals are an essential habitat for many of the hundreds of thousands of species associated with coral reefs. (Photographs courtesy of Katharina Fabricius, Australian Institute of Marine Science.)

The GBR was formally protected as a marine park in 1975. Management today, led by the GBR Marine Park Authority, is a sophisticated process linking natural and social sciences to provide the best possible outcomes for the GBR and its human users by reducing the stressors that can be controlled, particularly overfishing and poor water quality (6). Most notably, over 33% of the GBR was set aside as no-take areas in a major rezoning in 2004, a nontrivial political feat given the numerous competing uses for the GBR due to its proximity to major population centers and intensive agriculture. Thus, if this substantial and already challenging effort is failing, it begs the question as to what the response should now be.

A big part of the answer lies in the details of the data reported. Not surprisingly, there is a lot of heterogeneity across the reef in the extent of degradation. The northern portion of the GBR (Fig. 1*A*) is far from people and hovered around an average of 24% coral cover over the interval studied. In contrast, coral cover declined from 26.4% to 14.1% in the central region and from 37.4% to 8.2% in the south. Data showing that more remote reefs have not declined provide additional support for the notion that protection against local stressors is our best management bet in the context of global change (7), a strategy that is often referred to as managing reefs (and other ecosystems) for ecological resilience (8). All reefs are subject to the vagaries of the natural environment; even in the absence of global warming, typhoons, cyclones, and hurricanes are routine events for most coral reefs. Thus, the ability to bounce back from these and other disturbances is critical.

What kind of interventions might be feasible? Unfortunately, global warming is tied to the frequency of coral bleaching events (9) (and quite possibly to the intensity of severe storms), and there seems to be little on the horizon that will much improve the near-term outlook for these two sources of mortality. However, reducing the intensity and frequency of crown-of-thorns outbreaks is, although difficult, more doable. These outbreaks are likely the result of both top-down (removal of predators on the seastars) (1)

Author contributions: N.K. wrote the paper.

The author declares no conflict of interest.

See companion article on page 17995.

[1]E-mail: knowlton@si.edu.

and bottom-up (increasing the supply of nutrients to seastar larvae) (10) ecological processes, both of which can be managed locally through fishing restrictions and water quality policies. With respect to the latter, there is still much room for improvement. As De'ath et al. (2) note, the nutrient and sediment load of central and southern rivers is now five to nine times higher than it was before European colonization, and models suggest that crown-of-thorns outbreaks used to occur just once every 50–80 y, rather than once every 15 y currently. The authors suggest that if crown-of-thorns predation were eliminated, coral cover could increase by 0.89% annually, even with continuing mortality from bleaching and typhoons.

The projection for the future in the absence of intervention is not a pretty one. The authors argue that if current trends continue, the cover of living coral in the central and southern regions of the GBR will fall to 5–10% within a decade, comparable to the highly degraded reefs of the Caribbean (3). Moreover, this projection does not directly incorporate the effects of ocean acidification, which is likely to make an already bad situation worse, although the effects remain difficult to predict in detail (11).

Coral reefs are arguably the most diverse of all marine ecosystems and are certainly so on a per-area basis, providing shelter to hundreds of thousands of species (Fig. 1*E*). Their value to human society is considerable, perhaps as much US$30 billion per year (12), and many reefs flank the shores of developing countries that can least afford to lose them (13). Thus, the stakes and challenges could not be higher and are not limited to this Australian reef icon.

1. McCook LJ, et al. (2010) Adaptive management of the Great Barrier Reef: A globally significant demonstration of the benefits of networks of marine reserves. *Proc Natl Acad Sci USA* 107(43):18278–18285.
2. De'ath G, Fabricius KE, Sweatman H, Puotinen M (2012) The 27-year decline of coral cover on the Great Barrier Reef and its causes. *Proc Natl Acad Sci USA* 109: 17995–17999.
3. Gardner TA, Côté IM, Gill JA, Grant A, Watkinson AR (2003) Long-term region-wide declines in Caribbean corals. *Science* 301(5635):958–960.
4. Bruno JF, Selig ER (2007) Regional decline of coral cover in the Indo-Pacific: Timing, extent, and subregional comparisons. *PLoS ONE* 2(8):e711.
5. Sweatman H, Delean S, Syms C (2011) Assessing loss of coral cover on Australia's Great Barrier Reef over two decades, with implications for longer-term trends. *Coral Reefs* 30:521–531.
6. Day JC (2011) Protecting Australia's Great Barrier Reef. *Solutions* 2:56–66.
7. Knowlton N, Jackson JBC (2008) Shifting baselines, local impacts, and global change on coral reefs. *PLoS Biol* 6(2):e54.
8. Hughes TP, Graham NAJ, Jackson JBC, Mumby PJ, Steneck RS (2010) Rising to the challenge of sustaining coral reef resilience. *Trends Ecol Evol* 25(11):633–642.
9. Frieler K, et al. (2012) Limiting global warming to 2 °C is unlikely to save most coral reefs. *Nature Climate Change*, 10.1038/nclimate1674.
10. Fabricius KE, Okaji K, De'ath G (2010) Three lines of evidence to link outbreaks of the crown-of-thorns seastar *Acanthaster planci* to the release of larval food limitation. *Coral Reefs* 29:593–605.
11. Pandolfi JM, Connolly SR, Marshall DJ, Cohen AL (2011) Projecting coral reef futures under global warming and ocean acidification. *Science* 333(6041): 418–422.
12. Conservation International (2008) *Economic Values of Coral Reefs, Mangroves, and Seagrasses: A Global Compilation* (Center for Applied Biodiversity Science, Conservation International, Arlington, VA).
13. Donner SD, Potere D (2007) The inequity of the global threat to coral reefs. *Bioscience* 57:214–215.