Bleaching: The Greatest Threat to Corals

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Introduction

The calcium carbonate skeletons of corals in aggregate form reefs, which provide habitat for thousands to millions of marine species in tropical ocean desserts. Coral reefs support more species per unit area than any other marine environment, and scientists estimate that there may be another 1 to 8 million undiscovered species of organisms living in and around reefs (Reaka-Kudla, 1997). Reefs are critical to the survival of subsistence-dependent societies and are also valuable to wider economies for coastal protection, fisheries, and tourism. A widely accepted but outdated – and thus, conservative – estimate for the direct global value of reefs is $29.8 billion (Cesar *et al*., 2003). This estimate does not include more intangible benefits, such as existence value or protection of biodiversity. However, as our ever-increasing carbon dioxide (CO_2) emissions continue to alter the climate system, warming temperatures in the ocean threaten the health and survival of coral reefs. Sea subsurface and surface temperature increases disintegrate the symbiotic relationship between corals and algae in an event known as *bleaching*. Bleaching events are becoming increasingly common and are expected to increase in frequency in the twenty-first century (Donner *et al.*, 2005). Though coral reefs face many challenges, rising sea surface temperatures pose the greatest and most immediate threat to reef health.

The ocean is warming

The most recent assessment produced by the Intergovernmental Panel on Climate Change (IPCC) states that warming of the climate system is "unequivocal" (IPCC Summary for Policy Makers, 2013). Among the changes "unprecedented over decades and millennia" that have resulted from our runaway greenhouse gas emissions are atmospheric and ocean warming and sea level rise, which includes a substantial component due to thermal expansion (IPCC Summary for Policy Makers, 2013). The globally averaged combined land and ocean surface temperature data show a warming of around 0.85 °C from 1880 to 2012 (IPCC Summary for Policy Makers, 2013). According to the authors of the report, the ocean dominates the increase in global surface temperatures, accounting for more than 90% of the energy accumulated between 1971 and 2010 (IPCC Observations: Ocean, 2013). This figure is based on numerous independent observations

of subsurface temperatures, sea surface temperature, and sea level rise (IPCC Observations: Ocean, 2013).

Corals are temperature-sensitive

Like many creatures, reef-building corals have a symbiotic relationship with other organisms: small dinoflagellates known as zooxanthellae. The coral provides shelter and nutrients for the zooxanthellae, and in return, the zooxanthellae provide sustenance for the coral through photosynthesis. Reef systems are nutrient-poor, and this tight recycling is essential for both species. More than 90% of the products of photosynthesis by the zooxanthellae are directly used by the coral to make proteins, fats, and carbohydrates, and to build its calcium carbonate skeleton (Barnes, 1987; Barnes and Hughes, 1999; Hoegh-Guldberg 2007; Lalli and Parsons, 1995; Levinton, 1995; Sumich, 1996). However, when temperatures exceed summer maxima by 1-2°C for 3 to 4 weeks, this obligatory symbiosis disintegrates with ejection of the zooxanthellae, known as bleaching (Hoegh-Guldberg 2007). Stressed corals can survive bleaching events if conditions return to a more favorable state, but bleaching and mortality become progressively worse as thermal anomalies intensify and lengthen (Hoegh-Guldberg 2007). Although mortality may not result, bleached corals have reduced growth, calcification, and repair capabilities following the bleaching event (Donner *et al.*, 2007). Research indicates that bleaching could become an annual or biannual occurrence for the vast majority of the world's coral reefs in the next 30-50 years (Donner *et al.*, 2007). Most studies suggest that corals have already exceeded their capacity for acclimation (Hoegh-Guldberg 1999). If emissions continue unabated and the ocean continues to warm, scientists expect the loss and degradation of coral reefs on a global scale.

Rising temperatures exacerbate other problems

Many human impacts threaten coral reefs, including ocean acidification, sedimentation, overfishing, eutrophication, and destructive fishing methods. Each of these threats is likely to be more destructive in combination with temperature stress (Wilkinson and Buddemeier, 1994; Wilkinson, 1999). Increased rates of coral disease (Edmunds, 1991), the mass mortality of sea urchins (Hughes *et al.*, 1987) and outbreaks of corallivores such as crown-of-thorns starfish (*Acanthaster planci*; Moran, 1986) may also be linked to increased sea temperatures (Donner *et al.*, 2007). Many recent studies have focused on the effects of increased CO_2 concentrations in

the ocean. Present-day atmospheric CO_2 levels are estimated to be 30% higher than the natural range over the last 650,000 years, during which most marine organisms evolved; these levels are projected to double by the end of the century (Meehl *et al.* 2007). An estimated 30% of the anthropogenic CO_2 has been absorbed by the oceans (Feely *et al.*, 2004). Absorption alters carbonate chemistry and lowers pH, making it harder for corals to build their skeletons. Laboratory studies suggest that ocean acidification may pose a serious threat to reefs in the future, but field studies in a variety of locales demonstrate that daily pH variability on reefs in many cases exceeds the mean pH shift expected for the open ocean by 2100 (Teneva *et al.* 2013). This suggests that many reefs may be able to adapt to a lower pH, at least to the levels expected in this century. The same cannot be said for increased temperatures, to which scientists expect corals will not be able to further acclimate as the ocean warms rapidly over the next one hundred years.

Conclusion

Coral reefs are one of the most unusual, most beautiful, and most economically and ecologically important ecosystems on the planet. Reefs are sensitive to a variety of human impacts because they inhabit shallow coastal waters, a space shared with human societies. We rely on reefs for physical and spiritual sustenance, and it is our responsibility as a society to mobilize our resources for their protection. Studies demonstrate that the warming caused by our CO_2 emissions poses a serious threat to corals by causing them to eject their symbionts in an event known as *bleaching*. Bleaching exacerbates other anthropogenic and natural threats to reefs and is a serious concern in its own right. Bleaching has already begun to occur with increasing frequency, and it will become ever more common in the coming decades. All nations should adopt coral bleaching monitoring programs in order to understand the threat and to limit its impact on reef ecosystems and the people that depend upon them. Furthermore, all nations should adopt strict CO_2 emissions restrictions in order to limit warming and prevent future bleaching events.

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