Ocean warming and acidification deliver double blow to coral reefs

Under business-as-usual conditions, corals start dissolving into the oceans.

by **Jeremy Jacquot** - Sept 30 2013, 11:38am EDT

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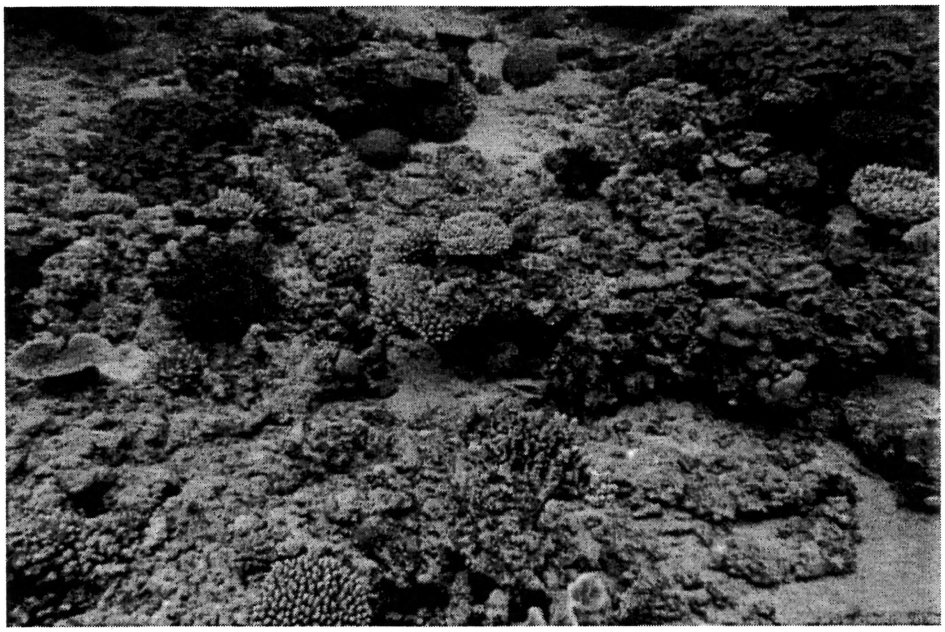

Great Barrier Reef coral assemblages

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The dual threats of ocean acidification and anthropogenic warming have the potential to wreak havoc on marine life over the coming decades. Corals require acid-sensitive calcium carbonate for structure and heat-sensitive symbionts for sustenance, so they seem to have the most to lose from a warmer, more acidic ocean. Indeed, numerous studies have already indicated that calcifying organisms, including corals, would be among the worst to suffer.

Although many studies have looked at heat and acidification, few have addressed the possible synergistic effects of these processes on intact coral reefs. To that end, a team of Australian researchers exposed patches of coral reefs to varying seawater temperature and pH conditions associated with a range of CO_2 emission scenarios. Their findings, though nuanced, do not bode well for the long-term well-being of coral reefs.

At its core, the study aimed to answer two questions with important ramifications for the future of coral reefs. First, how do current reef calcification rates compare to those of pre-industrial conditions? Second, will reefs respond differently to a possible future in which emission growth continues unabated versus one in which growth is moderately curbed?

Setting up the experiment

In order to better understand how corals—as members of a community rather than individuals—might respond to future conditions, the authors "built" replicate patches by piecing together species collected from the Great Barrier Reef. (The Reef doubled as the control, or reference, site for their experiment.) The coral reef patches were composed of a mixture of hard corals, macroalgae,

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article questions

1. Define anthropogenic warming.
2. What is the coral structure that is sensitive to low pH?
3. Describe the purpose of the study conducted in the article.
4. Describe the basic setup of the study.
5. The emissions scenarios in the study were based on the work of what organization?
6. Describe the results of the study.
7. What was the conclusion of the study?

vertebrates, and invertebrates, all of which were collected locally from a shallow depth. The underlying sediments and structure were made up of the skeletons of corals, calcareous algae, foraminifers (shelled amoeba-like protists), and mollusks.

Each patch was placed in a separate enclosed tank, and a continuous supply of warm/cold seawater and CO_2 was piped in. The tank lids were clear to let sunlight to come in. A buoy at the reference site allowed them to monitor daily and monthly variability in temperature and partial pressure of CO_2. They then incorporated this natural variability into their experiment.

The four emission scenarios they picked matched those used by several Intergovernmental Panel on Climate Change modeling studies. The first two correspond to pre-industrial and present-day conditions, while the latter two correspond to the low and high ends of future emission scenarios. Pre-industrial conditions were simulated by lowering the present-day seawater temperature (~24.3 to 27.8°C, depending on monthly variability) and increasing pH (~8.1) by 1°C and 0.1 unit, respectively. For the lower end of the future scenarios, which assumes some level of emission reductions, the temperature and pH were increased and lowered by 2°C and 0.2 unit, respectively. For the higher end, which assumes unabated or "business-as-usual" emission growth, the temperature and pH were increased and lowered by 4°C and 0.4 unit, respectively. Three replicate patches were assembled for each emission scenario.

Prior to beginning their observations, the authors gave the coral reef patches two and a half months to acclimate to the various treatment conditions by slowly mixing more treatment water with water from the inner reef. The experiment then ran throughout most of the austral summer, when temperatures and partial pressures of CO_2 are expected to be highest. Calcification rate and net primary productivity measurements were made over several days on three separate occasions.

The results

As expected, the coral reef patches reacted differently to each emission scenario. Incidences of coral bleaching and mortality varied widely, with the highest number occurring in the business-as-usual emission scenario and the lowest occurring in pre-industrial conditions. Most corals had already begun to pale by the beginning of November under business-as-usual conditions, while corals in the reduced emission and control scenarios only began to experience widespread bleaching by early February.The level of bleaching observed in the control scenario was similar to that observed in the Great Barrier Reef reference site.

While many corals were able to rebound from their bleaching episodes, those growing in the reduced and business-as-usual emission scenarios were much more likely to die. But those in pre-industrial conditions had little to rebound from. Only one thermally sensitive coral species experienced bleaching in that scenario.

Net primary productivity rates varied by month but were generally highest in December and lowest in November. Surprisingly, they showed little to no variation across the four experimental treatments, suggesting that some members of the patch may be able to pick up the slack as others falter.

Calcification rates, on the other hand, were strongly correlated with each treatment. Rates were consistently negative during the business-as-usual scenario, indicating the active loss of calcium carbonate from the reef. They were positive, though only slightly so, under the reduced emission conditions. The rates were higher and highest during the control and pre-industrial emission scenarios, respectively. Carbonate dissolution rates were highest at night, particularly under the business-as-usual scenario, but they also increased during the reduced and control emission scenarios as summer progressed. The authors attribute this to higher nocturnal CO_2 concentrations from aerobic respiration.

Taken together, these results demonstrate that, yes, coral reefs are likely to respond differently to varying future emission scenarios, with higher emissions resulting in higher mortality and decalcification rates. The fact that coral reef patches fared much better in the pre-industrial emission scenario than in the control scenario suggests that coral reefs have not had enough time to adapt to the relatively minor changes in seawater temperature and pH that have occurred over the past century. This matters, because some researchers have postulated that corals and their symbionts may be able to co-evolve in order to adapt to an even more hostile future ocean.

While their collective outlook seems decidedly bleak, there is some indication that certain coral species are already better equipped to deal with decreasing seawater pH, while others may actually benefit from rising temperatures. Coral reefs are found in shallow waters around the world—and even at depth—so there is likely to be a high degree of variability in how different species and assemblages are able to cope and adapt to changing environmental conditions.

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