Response of Coral Reef Builders to Changes in Ocean Chemistry

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Statement of Issue

GLOBAL climate change and the extensive coral bleaching that occurred in 1997-98 has been a source of wide-spread concern among scientists, managers and policy makers. Research indicates that rising sea temperatures associated with global climate change have been responsible for recent large scale bleaching and mortality events. However, increases in sea temperature are not the only concern to coral reef ecosystems from global climate change. There is also evidence that coral calcification will decline due to the direct influence of carbon dioxide (CO_2) on sea water chemistry. In essence, increased absorption of carbon dioxide into the oceans increases acidity, which lowers the ability of corals to generate their skeletons. The direct impacts of changes in carbon dioxide concentrations and ocean chemistry on coral reef organisms and ecosystems are the focus of current research. Relevant findings presented at the 9th ICRS are discussed below.

State of Knowledge

Increase in CO_2 leads to decrease in calcification
Surface ocean chemistry is changing in response to increased atmospheric CO_2 concentrations, and the magnitude of these changes is larger than that experienced by coral reefs for at least 420,000 years, and probably for many millions of years. The oceans' increased uptake of atmospheric CO_2 leads to the formation of carbonic acid, which lowers both pH and carbonate ion concentration. These changes are highly predictable and have been tracked with ocean measurements for over two decades.

In aquarium and mesocosm studies, both scleractinian corals and coralline algae exhibit an essentially linear decrease in calcification in response to these ocean chemistry changes, and primarily to the carbonate ion concentration. The relative decrease in calcification varies between species, and can be dramatic, with coralline algae generally exhibiting a slightly stronger calcification response (25-44 percent) than corals (19-27 percent) to doubled CO_2 conditions. These experiments have been conducted from hours to years, with no adaptive response indicated among the organisms tested.

Implications for coral reefs
At the organismal scale, it is likely that reduced calcification of corals and algae will be expressed as a decrease in extension rate, reduced density (greater fragility), and/or a change in growth form. Within coral reef communities, reduced calcification translates into reduced competitiveness for space, and because the various coral and algae species are likely to exhibit reduced calcification to different degrees, this will likely lead to shifts in community structure. On a larger scale, coral reefs represent the *net* accumulation of calcium carbonate produced by coral reef communities; while the growth of some reef organisms are contributing calcium carbonate, such as corals and coralline algae, other reef organisms are constantly removing calcium carbonate through bioerosion, such as burrowing organisms. Since $CaCO_3$ removal processes are naturally high, a net reduction in $CaCO_3$ production will result in slower or even negative reef growth.


Photo: Chris Langdon
Laboratory facility in Biosphere

Although atmospheric CO_2 had already increased by 25 percent by 1990, and despite the consistent laboratory results showing that calcification of reef builders declines in response to changes in seawater chemistry, coral cores from massive *Porites* colonies (through about 1990) on the Great Barrier Reef do not exhibit an industrial age decrease in calcification. The possible reasons for the laboratory/field mismatch in findings include: (1) massive *Porites* exhibits a smaller calcification response to increased pCO_2; (2) the response is overprinted by some other variable that affects calcification (for example, light and temperature); (3)

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dissolution of $CaCO_3$ sediments provides local buffering of seawater chemistry; and/or (4) some undetected flaw in laboratory studies.

Relevant Actions Being Taken to Address Issue

- As more experiments are conducted on different species and different species assemblages, our knowledge of how specific taxa and coral communities will respond to increased atmospheric CO_2 is improving.
- Although coral and algal calcification appears to behave geochemically (i.e. reflecting surrounding seawater chemistry), physiological studies indicate that the internal biochemistry of these organisms is complex. Several groups have tackled this problem using radioactive tracers to understand how Ca^{2+} and CO_3^{2-} ions are tranported by the organism to the site of calcification.
- $CaCO_3$ saturation state obviously exerts control on coral calcification, but other variables such as light, temperature and nutrients also play a role. Several researchers are attempting to define how these four variables interact to control calcification rate in corals.
- Recent evidence shows that not only will calcification decrease in the future, but dissolution will increase. Quantifying dissolution of carbonate minerals on coral reefs is difficult, but necessary if we are to understand how reef-building processes will change in the future.

Management and Policy Implications

Unlike other major impacts on coral reefs (bleaching, overfishing, etc.), changes in seawater chemistry are truly global in nature, with little evidence of significant regional differences. Future changes in surface seawater carbonate chemistry are directly linked to atmospheric CO_2 concentration, and are therefore highly predictable. In terms of policy, the only perceivable way to stop or reverse the effects of seawater chemistry on corals is to control CO_2 emissions.

In the meantime, managers of our coral reefs may be faced with increasing problems associated with decreased calcification on reefs. Coral communities may experience changes in community structure or a reduced competitiveness with other benthic taxa (both of which will be impossible to attribute to calcification changes alone). Also, unlike the acute effects of coral bleaching, decreases in calcification rate are chronic. These two factors render management difficult, because such effects occur over long time scales and are difficult to measure. As a consequence, reduced calcification on reefs is often not considered an immediate problem, particularly in comparison to mass mortalities associated with coral bleaching. This attitude is understandable, but incomplete in terms of planning for long-term reef survival.

Specific Recommendations for Action

- Reduce other anthropogenic sources of reef stress and degradation.
- Educate reef managers, and also policy makers and the general public about the impacts of changing seawater chemistry on coral reefs; encourage reductions in greenhouse gas emissions.
- Support studies to elucidate: (1) links between coral physiology and calcification; (2) effects of other variables on calcification; (3) species-specific response to seawater chemistry changes; (4) role of dissolution in carbonate budgets on reefs; (5) coral community ecosystem responses to increased atmospheric CO_2.
- Scale up aquarium and mesocosm experiments to field-scale CO_2 "fertilization" experiments. Field experiments will include the effects of natural variability of temperature and light, and will also allow observations of community response.
- Conduct longer term experiments designed to examine coral response to decreased calcification, and how this response is reflected in density, extension, and isotopic composition of growth bands.

Useful References and Resources

This paper is based upon presentations at the 9th International Coral Reef Symposium, Mini-Symposium E1, *Global Climate Change and Coral Reefs: The Science Behind the Prognostications of Gloom*. Authors and titles of presentations can be found at: http://www.nova.edu/ocean/9icrs/

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