### BIOSPHERE 2 STUDIES REFLECT REAL WORLD CHANGES

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Levels of carbon dioxide, a greenhouse gas found in the earth's atmosphere, have increased since pre-industrialized times, primarily due to the combustion of fossil fuels. Scientific studies have suggested this trend will continue, resulting in a projected doubling of atmospheric carbon dioxide levels from preindustrial levels by the year 2065.

This projected atmospheric change brings with it other potential and uncertain changes to the earth's atmosphere, biosphere and hydrosphere. Data collected from large-scale ocean surveys, for example, have indicated that surface waters of temperate and tropical oceans are taking up carbon dioxide in proportion to the earth's atmosphere.

Inside Columbia University's Biosphere 2 Center in Oracle, Ariz., Lamont-Doherty Earth Observatory Associate Research Scientist Chris Langdon directly tested and assessed the impact of elevated atmospheric carbon dioxide on coral reef building and maintenance. The ocean biome, one of six ecosystems located inside the Biosphere 2 Center, provided an ideal site to study these effects.

Langdon's findings contributed, along with research conducted by other scientists, to a paper recently published in the journal Science , titled, "Geochemical consequences of increased atmospheric CO2 on coral reefs." The paper suggests that atmospheric changes in carbon dioxide levels could lead logically to negative changes in reef structure, coral reproduction, and overall function of coral reef communities.

"Chris' work at Biosphere 2 was invaluable to our analysis," said Joan A. Kleypas, a researcher at the National Center for Atmospheric Research in Boulder, Colo., who was the paper's primary author. "When we put this paper together, his results were the only 'ecosystem' results available. I think [the ocean biome at Biosphere 2] is presently the best available system for studies of reef response to ocean chemistry changes."

Coral reefs serve many important functions, explains Langdon, as barriers protecting low-lying islands from erosion, habitats for diverse ecosystems, and aesthetically attractive areas that support a large tourism industry. A reef forms when corals and other marine organisms produce calcium carbonate, the solid substance found in limestone, bones and sea shells, primarily as the mineral aragonite.

In temperate and tropical shallow ocean areas with dense coral populations, this aragonite can accumulate to form reefs. For a reef community to build and maintain itself, the rate at which organisms deposit calcium carbonate must exceed the combined rates of physical, biological and chemical erosion of the reef.

The reef-building process can be influenced by the level of carbon dioxide in the water, through a chemical process that weakens bonds of the calcium carbonate molecules that form reefs. Currently, surface ocean water is predominantly supersaturated with calcium carbonate, but the research reported in Science suggests the saturation state will decrease as atmospheric carbon dioxide levels increase.

This lowered saturation state can result in decreased rates of calcification, the process by which many coral species build reefs. In addition to its negative effects on reef building rates, a decreased saturation state may also reduce the strength of a reef's cementation processes, resulting in a weaker structure more susceptible to erosion.

Langdon likens this structural weakening to osteoporosis, and explains that rising sea levels, which may result as increased temperatures caused by increased atmospheric carbon dioxide levels melt the polar ice caps, can further enhance erosion processes.

To help draw a clear picture of the potential effects of atmospheric carbon dioxide levels on coral reef building and maintenance, Langdon raised the carbon dioxide level of the atmosphere in the ocean biome of the Biosphere 2 Center. By taking water chemistry measurements, he could detect a correlating drop in the saturation state of aragonite in the water. He found this drop had a significant effect on decreasing the amount of calcium carbonate in the water, thereby also decreasing the growth rate of the coral reef.

Said Kleypas, "The fact that the Biosphere 2 mesocosm illustrated the same response to changes in saturation state as that of individual coral and marine alga in aquaria increases our confidence that the system responses at aquarium, or mesocosm, scales can be extrapolated to the field."

These findings have important global implications, since measurements of the saturation state of aragonite in surface ocean water show that it has been decreasing. In the past 100 years, for example, the average aragonite saturation state in the tropics has dropped about 10 percent.

It is predicted this tend will continue, amounting to an average decrease of about 40 percent by the year 2100 from preindustrial levels. Precipitation, the process by which aragonite and other calcium carbonate minerals produced by corals solidify into reefs, also is expected to decrease, by 17 to 35 percent from preindustrial times to 2100.

Reefs that may be the most vulnerable to these changes are those with balanced calcium carbonate budgets, characterized by rates of growth that equal their rates of erosion. Any decrease in the calcium carbonate produced by these reefs, located primarily in high-latitude areas like Bermuda and deep-water upwelling regions like the Galpagos Islands, could corrupt this balance, leading to reef-building rates that could not compete with higher rates of erosion.

Though it has been evidenced that productive reef ecosystems do emit some carbon dioxide into the atmosphere, and that a decrease in the total surface area of reefs globally would decrease this level of emission, research has not indicated this decrease will have a significant effect on lowering atmospheric levels of carbon dioxide.

Currently, scientific estimates state reef-to-atmosphere emissions of carbon dioxide only amount to one percent of human-to-atmosphere emissions of this gas due to fossil fuel combustion. This research study indicates this discrepancy will become even wider, as reef emissions of atmospheric carbon dioxide are expected to decrease while anthropologic emissions are expected only to increase.

By Robert J. Nelson