XI. Coral Reefs

> ***AIT*:** "Many factors contribute to the death of coral reefs—pollution from nearby shores, destructive dynamite fishing in less developed regions, and more acidic ocean waters. However, the most deadly cause of the recent, rapid, and unprecedented deterioration of coral reefs is believed by scientists to be higher ocean temperatures due to global warming." (*AIT*, p. 164)

Comment: The deteriorating condition of coral reefs predates by decades any significant warming from greenhouse gases. Pandolfi et al. (2003), a team of a dozen biologists who surveyed 14 of the earth's major reef systems, found that "most…were substantially degraded before 1900," and that "all of the reefs in our survey were substantially degraded long before the first observations of mass mortality resulting from bleaching and outbreaks of disease."[1] Corals could probably survive and even thrive in a warming world if they were not weakened and traumatized by pollution, sediment loading, and a host of other local insults.

As the Center for the Study of Carbon Dioxide and Global Change points out, the scleractinian corals, which are today's main reef builders, emerged in the mid-Triassic Period, when the Earth was "considerably warmer" than today, and thrived "throughout the Cretaceous, even when temperatures were 10-15°C higher than at present."[2] During the Paleocene/Eocene thermal maximum of ~55 million years ago, Arctic sea surface temperatures reached 24°C (75°F),[3] implying much warmer-than-present SSTs in the tropical oceans. Gore's own graph on pages 66-67 shows that all four previous interglacial periods were warmer than the one in which we are now living. Analysis of coral skeletal remains from Australia's Great Barrier Reef indicates that the tropical ocean about 5,350 years ago was 1.2°C warmer than the mean for the early 1990s.[4] In short, today's coral species have been around for 200 million years and survived countless changes in the global environment. If global warming were the coral killer Gore makes it out to be, coral would have become extinct long ago.

It is far from clear that warming per se is bad for coral. One study "suggests that ocean warming will foster considerably faster future rates of coral reef growth that will eventually exceed pre-industrial rates by as much as 35 percent in 2100," according to lead author Ben McNeil, an oceanographer at the University of New South Wales.[5] McNeil is not talking about a trivial amount of warming but a hefty 3.2°C increase in annual mean sea temperatures at coral reefs during the period from 1950 to 2100. In addition to more robust coral growth, the study also predicts that warming will expand coral's habitat range.

> ***AIT*:** "In 2005, to date the hottest year on record, there was a massive loss of coral reefs, including some that were healthy and thriving when Columbus first arrived in the Caribbean." (*AIT*, p. 164)

Comment: Gore lists no source for the claim of massive coral loss in 2005. He neglects to ask whether coral that were healthy and thriving in 1492 were still in good shape

before recent increases in SSTs.

> ***AIT*:** "In 1998, the second hottest year on record, the world lost an estimated 16% of all its coral reefs." (*AIT*, p. 164)

Comment: *AIT* does not mention that 1998 was the year of an unusually strong El Nino, the warm phase of a naturally recurring ocean cycle.[6] Although 16% of the world's reefs were seriously damaged in 1998, by 2003 about 40% of the damaged reefs were either "recovering well" or had "fully recovered," according to *Status of Coral Reefs of the World: 2004* (pp. 7-8).[7] Corals are more resilient than Gore seems to realize.

> ***AIT*:** "The link between global warming and the large-scale bleaching of corals, considered controversial only 10 to 15 years ago, is now universally accepted." (*AIT*, p. 166)

Comment: Corals are communities of tiny organisms—polyps—that live symbiotically with micro-algae that supply them with energy, nutrients, and color. Almost any adverse change in water temperature (too cold as well as too warm), chemistry (not salty enough), or quality (too murky) can cause the polyps to eject their symbiotic algae, "bleaching" the coral. But coral bleaching is not the same as coral death. Bleaching can be an opportunity for polyps to "switch partners," to recruit new symbionts better adapted to changed environmental conditions. Patrick Michaels comments:[8]

> Now, two new papers in *Science* add further evidence that corals must not be as "fragile" as certain senators might hope. Cynthia Lewis and Mary Coffroth of SUNY-Buffalo bleached Caribbean corals and exposed them to certain *Symbiodinium* genotypes for six weeks. The corals not only re-established symbiotic relationships with the algae, but in some cases they changed algae species, giving the corals a unique opportunity to select symbionts based upon the environmental conditions.
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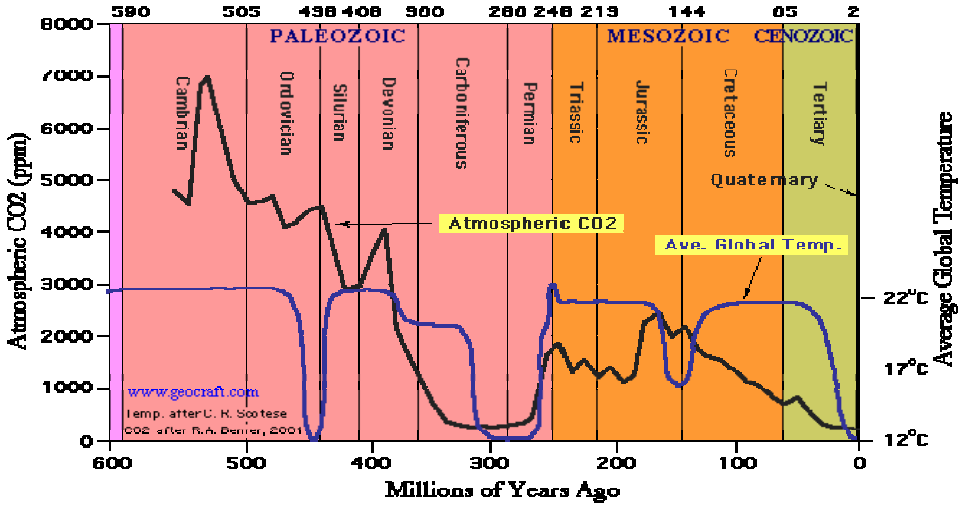
> The second *Science* paper, by Angela Little and two coauthors from Townsville, Australia, looked at changing symbiotic relationships over the lifetime of the corals. They found that young juvenile corals tended to interact with different *Symbiodinium* strains than did adults, which 'suggests that there maybe 'active' selection by the host to maximize symbiont effectiveness that varies with differences in physiological requirements between juvenile and adult corals.

Michaels concludes: "While coral bleaching appears to be mass suicide to uninformed senators, it could actually be an excellent adaptive strategy that has allowed the species to survive for millions of years."

> ***AIT*:** Gore worries that rising CO_2 levels in the air will increase carbonic acid levels in seawater, which in turn will decrease levels of calcium carbonate—the raw material coral polyps use to build reefs. He presents a chart showing that all

> optimal areas for reef construction will disappear by 2050 "if we allow the doubling of pre-industrial CO_2 levels—which will occur within 45 years unless we do something about it." (*AIT*, p. 169)

Comment: The claim that all optimal areas for reef construction will disappear if CO_2 concentrations reach a doubling of pre-industrial levels is not plausible. As noted above, the scleractinian corals emerged during the Mid-Triassic Period and thrived during the Cretaceous Period. During those periods, atmospheric CO_2 levels were several times current concentrations. See the Figure below.



CO_2 levels and average global temperatures over geologic time
Source: Monte Hieb[9]

Given this history, how plausible is it that raising CO_2 concentrations to 560 ppm—roughly double pre-industrial levels—would make the oceans almost uninhabitable for corals?

The source of Gore's gloomy forecast is the U.S. Global Change Research Program (USGCRP).[10] The USGCRP's source, in turn, is Kleypas et al. (1999), which predicts declining coral calcification rates from 1880 to 2050.[11] The Center for the Study of Carbon Dioxide and Global Change reviewed the literature on CO_2-induced changes in carbonate levels, including Kleypas et al., and found that "none [of the studies] deal with living organisms, and, therefore, that *none* of them deal with the actual calcification process *as driven by life processes*. Rather, they deal exclusively with the lifeless world of chemistry and thermodynamics."[12]

Accordingly, the Center also reviewed the marine *biology* literature on coral calcification. These studies find that coral calcification rates have *increased* as SSTs and CO_2 levels have risen. Three factors appear to be at work: (1) warmth promotes coral calcification; (2) higher CO_2 levels boost coral-symbiont photosynthesis; and (3) CO_2-stimulated bio-productivity raises marine pH levels, mitigating the effects of CO_2-induced increases in carbonic acid.

One excerpt from the Center's long review article must suffice to show that *AIT* does not present a balanced view of the science:

> Another pair of scientists to address the subject was Bessat and Buigues (2001),[13] who worked with a core retrieved from a massive *Porites* coral on the French Polynesian island of Moorea that covered the period 1801-1990, saying they undertook the study because they thought it "may provide information about long-term variability in the performance of coral reefs, allowing unnatural changes to be distinguished from natural variability." This effort revealed that a 1°C increase in water temperature increased coral calcification rate by 4.5%, and that "instead of a 6-14% decline in calcification over the past 100 years computed by the Kleypas group, the calcification has increased." They also observed patterns of "jumps or stages" in the record, which were characterized by an increase in the annual rate of calcification, particularly at the beginning of the past century "and in a more marked way around 1940, 1960 and 1976," stating once again that their results "do not confirm those predicted by the Kleypas *et al*. (1999) model…"

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[1] Pandolfi, J.M., E. Bradbury, R. H. Sala, T. P. Hughes, K.A. Bjorndal, R.G. Cooke, D. McArdle, L. McClenachan, M. J. H. Newman, G. Paredes, R. R. Warner, J.B.C. Jackson. 2003. Global trajectories of the long-term decline of coral reef systems. *Science* 301: 955-958.

[2] Center for the Study of Carbon Dioxide and Global Change, "A Pitiable Ploy to Promote the Kyoto Protocol: The Predicted Demise of Coral Reefs," 26 June 2002, http://www.co2science.org/scripts/CO2ScienceB2C/articles/V5/N26/EDIT.jsp.

[3] Moran, K., J. Backman, H. Brinkhuis, S.C. Clemens, T. Cronin, G. R. Dickens, F. Eynaud, J. Gattacceca, M. Jakobsson, R. W. Jordan, M. Kaminski, J. King, N. Koc, A. Krylov, N. Martinez, J. Matthiessen, D. McInroy, T. C. Moore, J. Onodera, M. O'Regan H. Pälike, B. Rea, D. Rio, T. Sakamoto, D. C. Smith, R. Stein, K. St John, I. Suto, N. Suzuki, K. Takahashi, M. Watanabe, M. Yamamoto, J. Farrell, M. Frank, P. Kubik, W. Jokat and Y. Kristoffersen. 2006. The Cenozoic paleoenvironment of the Arctic Ocean. *Nature* 411: 601-605.

[4] Beck, W. 1998. Warmer and wetter 6000 years ago? *Science* 279: 1003-1004.

[5] McNeil, B.I., R.J. Matear, D.J. Barnes. 2004. Coral reef calcification and climate change: The Effect of Ocean Warming. *Geophysical Research Letters*, Vol. 31, L223009, doic10.1029/2004/GL021541.

[6] U.S. Department of Commerce, El Nino Theme Page, http://www.pmel.noaa.gov/tao/elnino/nino-home.html.

[7] Clive Wilkinson, ed., *Status of Coral Reefs of the World: 2004*, Australian Institute of Marine Science, www.aims.gov.au/pages/research/coral-bleaching/scr2004/index.html

[8] Patrick Michaels, "Beached Bond," *World Climate Report*, June 7, 2004, http://www.worldclimatereport.com/index.php/2004/06/07/bleached-bond.

[9] http://www.clearlight.com/~mhieb/WVFossils/Carboniferous_climate.html. Although I cannot vouch for the details of this Figure, it is consistent with information provided by the Center for the Study of Carbon Dioxide and Global Change, "The Last 4.5 Billion Years," http://www.co2science.org/scripts/CO2ScienceB2C/subject/questions/1998/historic_co2.jsp.

[10] U.S. Global Change Research Program, *The Potential Consequences of Climate Variability and Change*, Figure 10, p. 608, http://www.usgcrp.gov/usgcrp/Library/nationalassessment/16C.pdf.

[11] Kleypas, J.A., R.W. Buddemeier, D. Archer, J-P. Gattuso, C. Langdon, and B.N. Opdyke 1999. Geochemical consequences of increased atmospheric carbon dioxide on coral reefs. *Science* **284**: 118-120.

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[12] Center for the Study of Carbon Dioxide and Global Change, "The Impact of Anthropogenic CO_2 Emissions on Calcifying Marine Organisms," 5 October 2005, http://www.co2science.org/scripts/CO2ScienceB2C/articles/V8/N40/EDIT.jsp.

[13] Bessat, F. and D. Buigues. 2001. Two centuries of variation in coral growth in a massive Porites colony from Moorea (French Polynesia): a response of ocean-atmosphere variability from south central Pacific. *Palaeogeography, Palaeoclimatology, Palaeoecology* 175: 381-392.