Expected impacts of climate change to coral reefs of the Pacific

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Coral reefs are of immense environmental, social and economic value to Pacific nations but they face many pressures, including fishing, land-sourced pollution, and climate change.[1] The purpose of this paper is to briefly summarise the threat of climate change to coral reefs in the Pacific and what the targets should be set to avoid severe impacts on coral reefs.

Climate change is expected to have severe impacts on many ecosystems in coming decades, but few ecosystems appear as vulnerable to these impacts as coral reefs.[2] It is expected to affect coral reefs predominantly through changes of three variables: increases in sea surface, temperature causing coral bleaching; increased ocean acidity leading to decreased calcification and growth rates in corals; and increases in sea level. In relation to coral bleaching the Intergovernmental Panel on Climate Change (IPCC) found that:[3] "Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1 to 3°C [above pre-industrial levels] are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals."

Coral bleaching. Photograph: Paul Marshall and Heidi Schuttenberg, *A Reef Manager's Guide to Coral Bleaching*.

The findings of the IPCC suggest that a rise of 1°C in mean global temperatures and, correspondingly, sea surface temperatures is the maximum that should be aimed for if the global community wishes to protect coral reefs. The range of 1-3°C is the danger zone and 2°C is not safe. Supporting this conclusion Ove Hoegh-Guldberg and his colleagues concluded in a major review of the likely impacts of climate change to Australia's Great Barrier Reef (GBR):[4] "Successive studies of the potential impacts of thermal stress on coral reefs have supported the notion that coral dominated reefs are likely to largely disappear with a 2°C rise in sea temperature over the next 100 years. This … suggests that coral dominated reefs will be rare or non-existent in the near future."

Stabilising Global Temperature Rises

The IPCC's best estimate of climate sensitivity found that stabilising greenhouse gases and aerosols at 350 parts per million carbon dioxide equivalents (ppm CO2-eq) would be expected to lead to a rise in mean global temperatures of 1°C above pre-industrial levels, stabilising at 450 ppm CO2-eq will lead to a rise of 2°C, and stabilising at 550 ppm CO2-eq will lead to a rise of 3°C.[5] Atmospheric concentrations of green-

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[1] For the most recent review of the state of coral reefs in the Pacific, see Wilkinson C, *Status of Coral Reefs of the World 2004* (Australian Institute of Marine Science, Townsville, 2004).

[2] See IPCC, *Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. WGII Contribution to the IPCC AR4* (Cambridge University Press, 2007), pp 12, 44, 320-322, 527 and 850-855, available at http://www.ipcc.ch/ipccreports/ar4-wg2.htm.

[3] IPCC, n 2, pp 12 and 852.

[4] Hoegh-Guldberg *et al*, "Vulnerability of reef-building corals on the Great Barrier Reef to climate change", Ch 10 in Johnson JE and Marshall PA (eds), *Climate Change and the GBR: A Vulnerability Assessment* (GBRMPA, 2007), p 295, http://www.gbrmpa.gov.au/__data/assets/pdf_file/0008/22598/chapter10-reef-building-corals.pdf.

[5] IPCC, *Climate Change 2007: The Physical Science Basis. Contribution of WGI to the AR4* (Cambridge University Press, 2007), Table 10.8, p 826, http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

house gases and aerosols have already passed 350 ppm CO2-eq making stabilisation at that level extremely difficult if not impossible in practice particularly in the context of current global growth and energy use patterns. Atmospheric CO2 reached 379 ppm in 2005 and was increasing by 2 ppm per year.[6] Including the effect of other greenhouse gases such as methane, the total concentration of atmospheric greenhouse gases was around 455ppm CO2-eq in 2005.[7] However, the cooling effects of aerosols and landuse changes reduce radiative forcing so that the net forcing of human activities was about 375 ppm CO2-eq for 2005.[8]

Global emissions of carbon dioxide, the major anthropogenic greenhouse gas, are growing at approximately 3% per annum, which exceeds even the "worst case" IPCC projections.[9] This places global greenhouse gas emissions on a trajectory to rise by 150% between 2000 and 2050 on "business as usual".

Required Levels of Reduction in Greenhouse Gas Emissions

A critical issue for future regulation of climate change is what level of reduction of anthropogenic greenhouse gas emissions is required to stabilise the rise in atmospheric greenhouse gas concentrations and, thereby, stabilise temperature rises. Figure 1 shows the results of the IPCC modelling for six stabilisation scenarios and the corresponding reductions in greenhouse gas emissions required globally by 2050.

Figure 1: IPCC stabilisation scenarios[10]

Stabilisation scenarios	Concentration of greenhouse gases (ppm CO_2–eq)	Global mean temperature increase (°C)	Percentage change in global CO_2 emissions 2000-2050 (%)
I	445 - 490	2.0 - 2.4	-85 to -50
II	490 - 535	2.4 - 2.8	-60 to -30
III	535 - 590	2.8 - 3.2	-30 to +5
IV	590 - 710	3.2 - 4.0	+10 to +60
V	710 - 855	4.0 - 4.9	+25 to +85
VI	855 - 1130	4.9 - 6.1	+90 to +140

When the conclusions of the IPCC are synthesised, it is clear that reductions of greenhouse emissions of 60% by 2050, such as proposed by the new Australian Government,[11] are not likely to prevent serious damage to the coral reefs in the Pacific or globally. A 60% reduction in global emissions by 2050 is likely to lead to a mean global temperature rise around 2.4°C, which is likely to severely degrade coral reefs globally. Stabilising greenhouse gases and aerosols around 350 ppm CO2-eq and allowing a rise in mean global temperature of 1°C appear to be the highest targets that should be set if coral reefs are to be protected from serious degradation.

Will We Leave the Coral Reefs of the Pacific for Our Children?

Based on our current policy response the answer to this question appears to be "no". That answer is not acceptable. We need to re-think our climate change policies and create policies that can credibly answer "yes" to this question. Whether it is technologically or economically feasible to return to 350 ppm CO2-eq and stabilise the global temperature rise at 1°C or less should not be determinative of this question. Policy-makers should set targets based on what we want to achieve. We should not accept targets that will produce unacceptable outcomes. To illustrate this point: if we want to build a bridge across a river that is 1km wide we would not ask our engineers and scientists to build us a bridge that was 500m long. We should apply the same logic to climate change policy and set targets for our engineers and scientists to achieve that produce results that we want to achieve. In this way protecting coral reefs can be used as a flagship ecosystem and a yardstick against which to measure dangerous climate change and, conversely, acceptable climate change.

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[6] IPCC, n 5, pp 2 and 137.

[7] IPCC, *Climate change 2007: Mitigation. Contribution of WGIII to the AR4* (Cambridge University Press, 2007), p 102. Available at http://www.ipcc.ch/ipccreports/ar4-wg3.htm.

[8] IPCC, n 7, p 102.

[9] Raupach MR, Marland G, Ciais P, Le Quéré C, Canadell JG, Klepper G, and Field CB, "Global and regional drivers of accelerating CO2 emissions" (2007) 104(24) PNAS 10288-10293, available at http://www.pnas.org/cgi/content/abstract/104/24/10288.

[10] Adapted from IPCC, *Climate Change 2007: Synthesis Report* (IPCC, 2007), Table 5.1, p 67, available at http://www.ipcc.ch/ipccreports/ar4-syr.htm.

[11] See generally, http://www.climatechange.gov.au.