Agree and ignore: the looming crisis for coral reef ecosystems

Ove Hoegh-Guldberg

Queensland Smart State Premier's Fellow, Global Change Institute University of Queensland
www.gci.uq.edu.au

I would like to begin by thanking Dr Pat Hutchings and the Royal Zoological Society of New South Wales for the invitation to talk today[1]. This is a very important time during the climate change debate, when science appears to be under increasing attack from some sectors of society that have an interest in preventing the Australian public from being exposed to this urgent and critical issue for the future of our nation.

I usually start my talks on coral reefs with pictures like these, which illustrate the beauty and importance of coral reef ecosystems. They are truly among the most spectacular ecosystems on the planet. Beautiful and magnificent, they provide habitat for over one million species, and are hugely important to biodiversity. At the heart of their structure are rich communities of reef-building corals which establish large geological structures that are visible from outer space.

They are also useful to humans through their contributions to fisheries, tourism and coastal protection. These services provide support for an estimated 500 million people across the planet, many of whom are desperately poor and need reefs to survive.

Even to a relatively rich country like Australia, coral reefs provide the basis for fast industries like tourism that bring in some $6 billion each year. The second largest employer in the state of Queensland is the tourist industry associated with the Great Barrier Reef.

Figure 1. Carbonate coral communities (a) at Heron Island, and (b) the Great Barrier Reef near Cairns as seen from the air.

1. The forum Science under Siege was held on 29 November 2008. This paper has been slightly updated for publication, but essentially it is the transcript of the presentation on the day. It remains as pressing as it did then, in fact, more so.

Pp99-106 in *Science under siege: zoology under threat*, edited by Peter Banks, Daniel Lunney and Chris Dickman. Royal Zoological Society of New South Wales, Mosman, NSW, Australia. 2012.

DOI : 10.7882/FS.2012.044

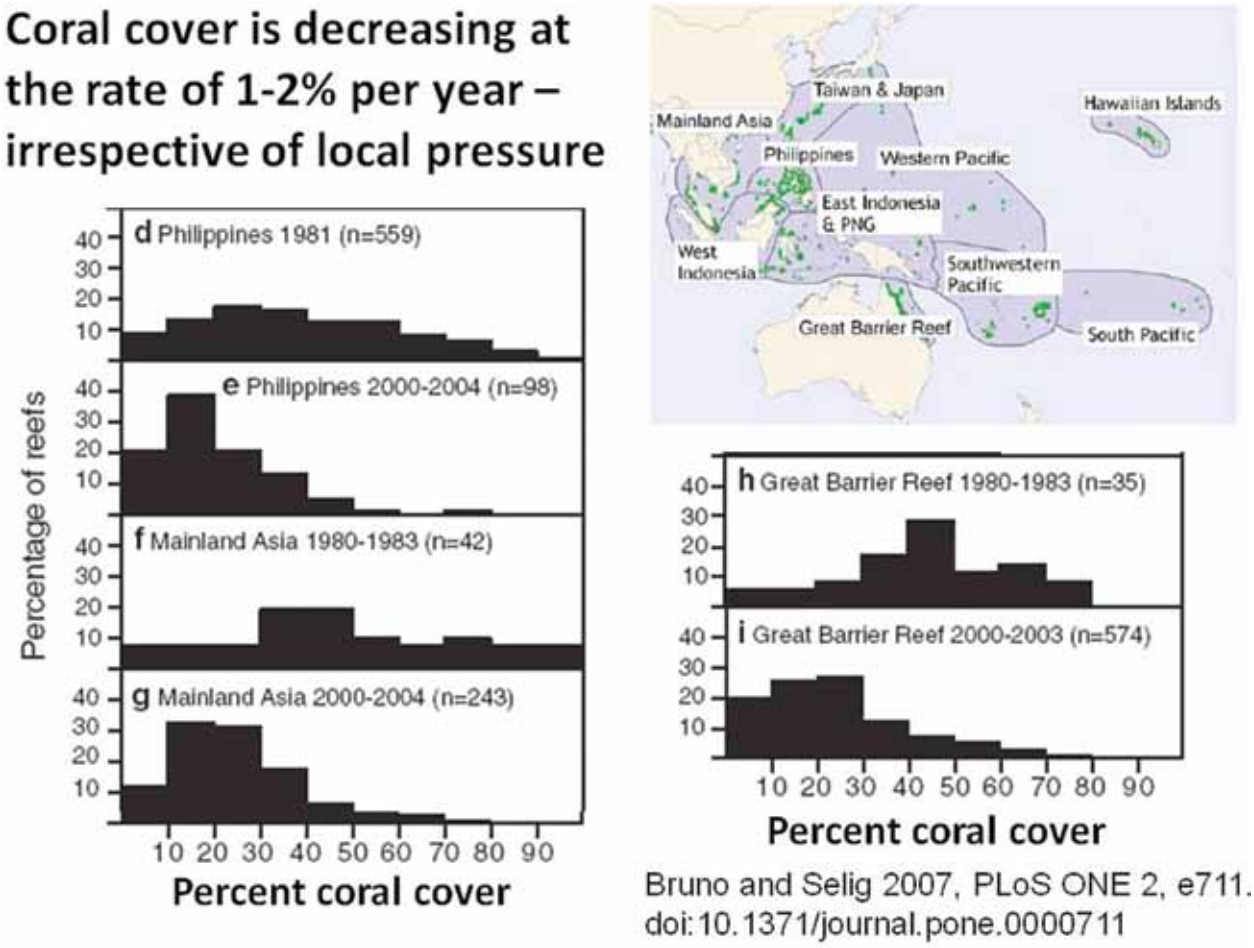

Figure 2. Comparison of coral cover in the 1980s to that found recently in the Philippines, mainland Asia, and on the Great Barrier Reef (Bruno and Selig 2007)

Despite their importance, there is now abundant evidence that coral reefs are facing troubling declines. The recent meta-study by Bruno and Selig (2007) indicated that coral cover, an indicator of reef health, is declining rapidly. This is a short snippet from their study, showing that reefs 30 years ago had roughly twice as much coral cover as they do today. The key observation from this study is that coral reefs throughout the Asia-Pacific region, including the Great Barrier Reef, have declined in coral cover by as much as 30-50% since the early 1980s. The implication that can be drawn from this is that coral reefs are declining at an annual rate of 1-2%.

This rapid rate of decline demands an explanation and this leads us to a number of factors. Like many other ecosystems on the planet, coral reefs are facing challenges on an unprecedented scale. Not only are coral reefs being impacted by local pressures, such as overexploitation and poor water quality, they are now facing serious stress arising from global pressures.

I shall now discuss the global pressures arising from climate change. After doing this, I want to try and understand why we are not responding with greater urgency.

Corals, which lie at the heart of coral reefs, are extremely sensitive to small changes in temperature. The well-known manifestation of this is coral bleaching which is where the symbiosis that exists between corals and dinoflagellate algae from the genus *Symbiodinium* falls apart (Figure 5). With respect to temperature, serious impacts on reefs, involving complete mortalities of corals, begin at 1°C above the summer maximum temperatures normal for a region.

It is important to point out that changes in coral reefs are not restricted just to reef-building corals. The impact of reducing the abundance of reef-building corals on tropical reefs has a large-scale impact on community composition, with at least 50% of fish species being vulnerable to loss. There are now dozens of examples where fish species have become locally extinct following damage to or the loss of reef-building corals. The implications of this loss for biological diversity and industries such as tourism and fisheries are extremely serious.

The second major factor facing coral reefs is the steady acidification of tropical oceans due to the rise of carbon dioxide in the atmosphere. This issue is seen by many as being potentially one of the most serious impacts of rising carbon dioxide in the atmosphere. Ocean acidification

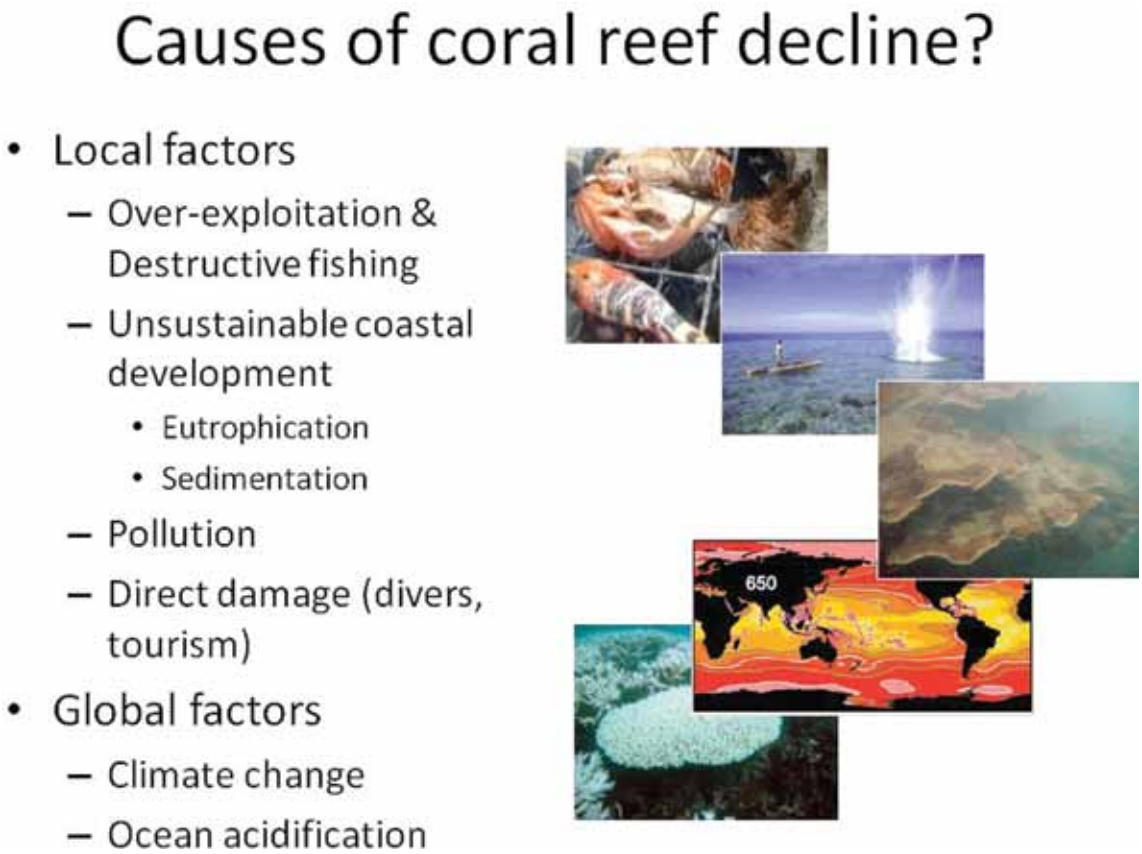

Figure 3: Reasons for the decline of coral reefs from a variety of scientific sources.

Figure 4. Picture of bleach corals at great Keppel Island, January 2006. Key threats from the rise of atmospheric carbon dioxide outlined.

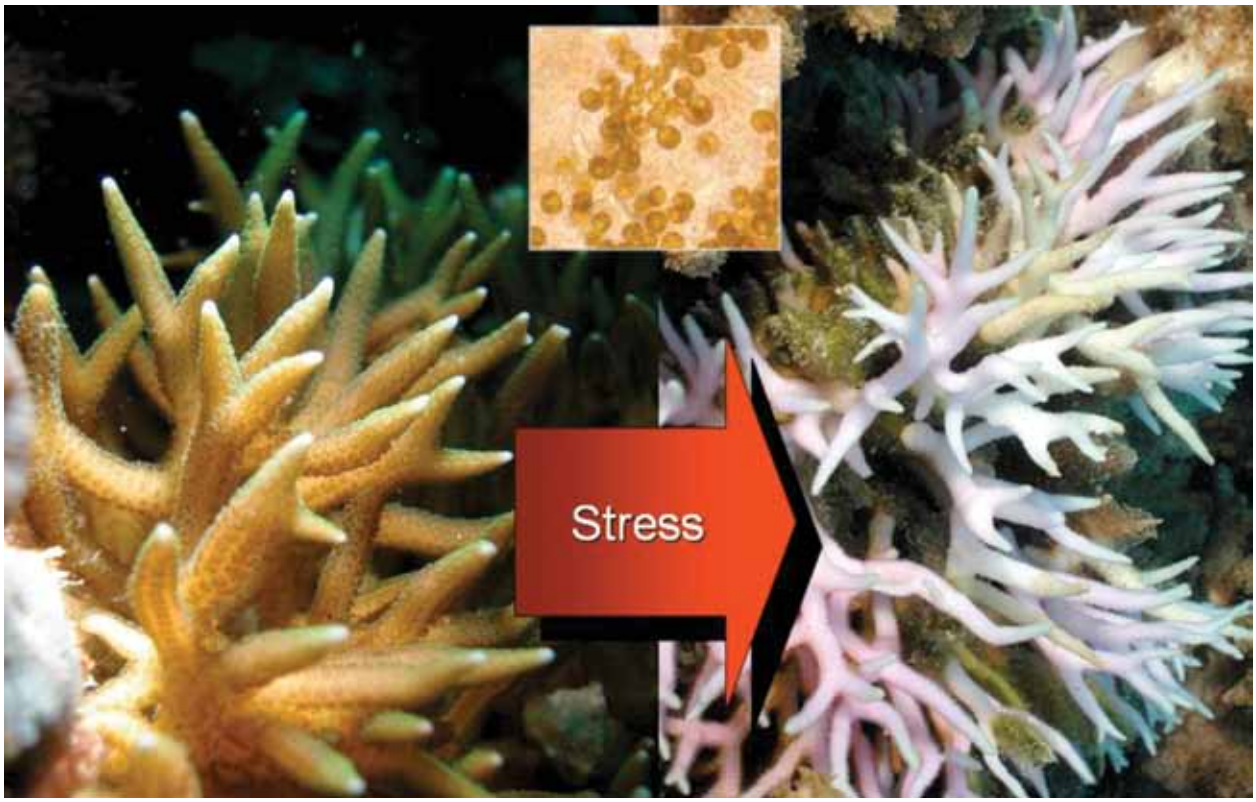

Figure 5. Bleaching illustrated: Brown, healthy colony on the left-hand is transformed into bleach coral on the right as *Symbiodinium* (shown in insert) leave the tissues of the coral during periods of stress. Coral species shown in B. is *Seriatopora hystrix*.

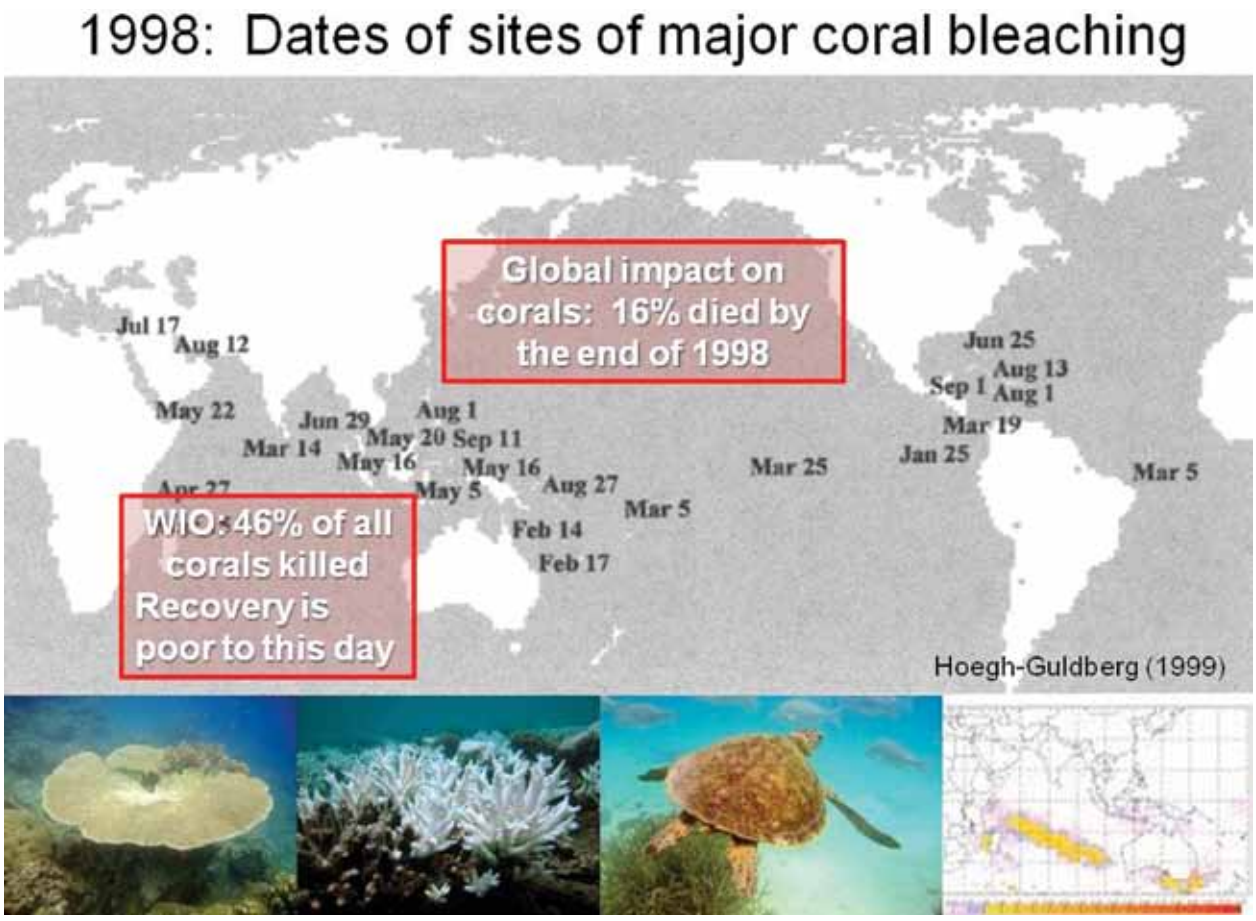

Figure 6: Dates at which mass coral bleaching was reported throughout the world in record warm year of 1998. Mortality following this event was significant, with 16% of corals dying by the end of 1998. In some regions, such as the western Indian Ocean, 46% of all corals were killed. To this day, recovery of many reef systems after this global event has been poor.

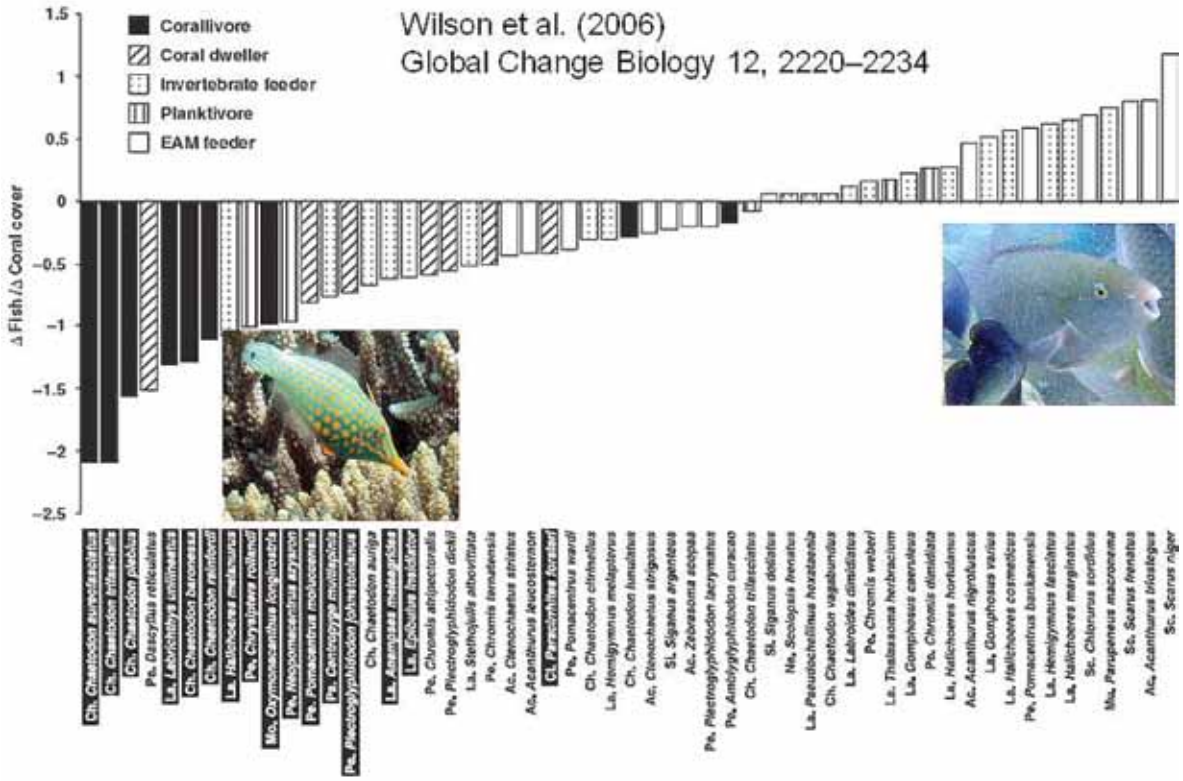

Figure 7. Response of 55 fish species to declining coral cover (Wilson 2006). Fish on the left-hand side tend to be coral specific (using coral for food, shelter and for reproduction) while fish on the right-hand side tend to be roving herbivores such as the parrotfish shown.

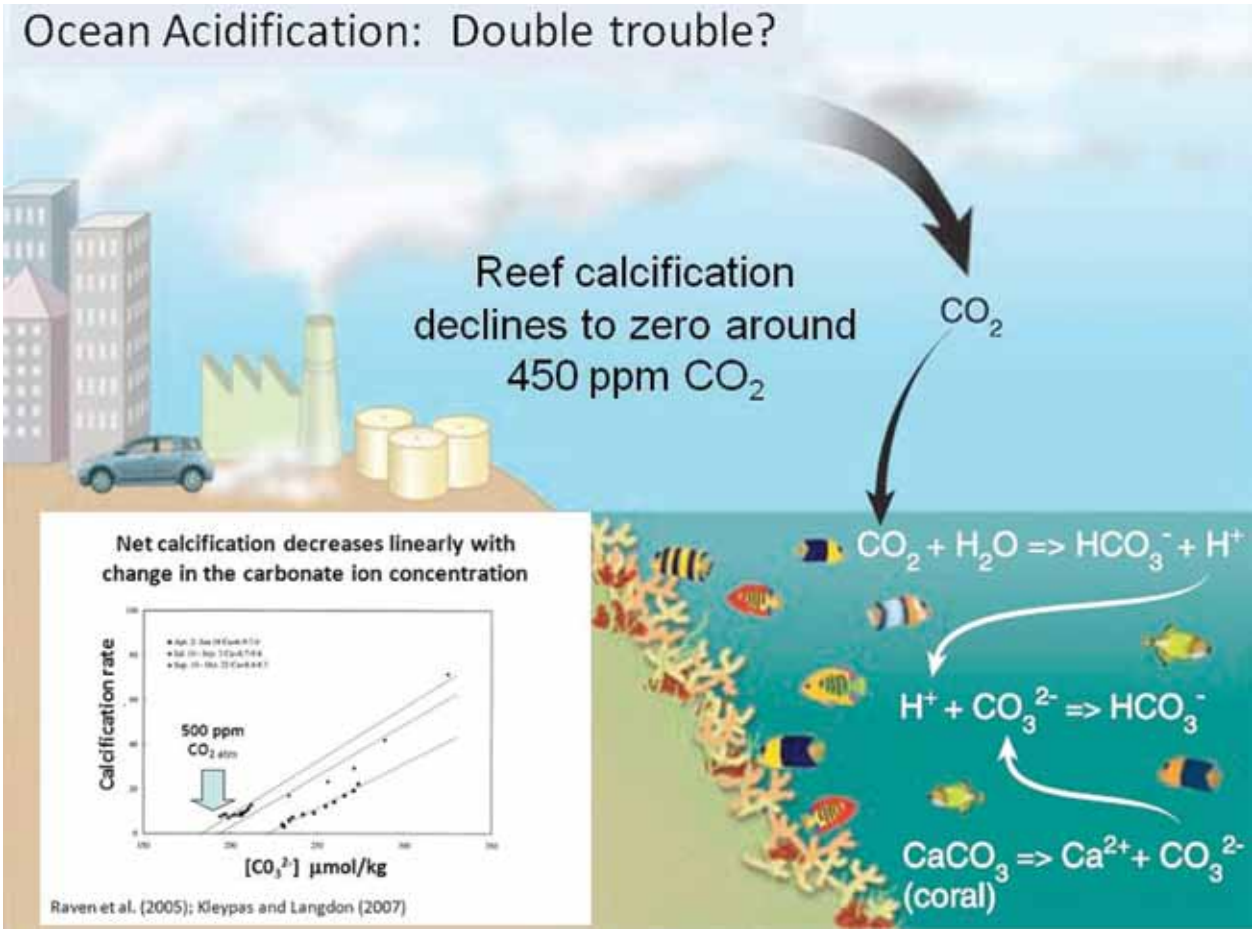

Figure 8: Ocean acidification arises due to the increased penetration of carbon dioxide into ocean waters, where it reacts with water to produce a dilute acid, carbonic acid. This decreases pH and leads to large-scale reduction in the availability of carbonate (CO3-2) ions, which are crucial for calcification (insert).

arises from the fact that carbon dioxide when it enters ocean reacts with water to create a dilute acid (carbonic acid). This acid disassociates and the proton that is released converts carbonate to bicarbonate.

There is now an abundance of studies that show strong impacts of declining pH and carbonate iron concentrations on the calcification of a range of organisms, including reef building corals (Kleypas and Langdon 2006). One of the most serious conclusions from the studies is that concentrations of carbon dioxide in the atmosphere that approach 450 ppm represent the limit for carbonate coral reef ecosystems.

Modelling studies show that the ocean chemistry that is required for carbonate-dominated coral reefs to persist in the world's oceans will disappear rapidly over the coming decades and century, if we continue to pump CO_2 into the atmosphere at the current rates (Figure 9). Another important conclusion from these studies is that we are currently outside conditions where coral reefs have been over the last 420,000 years (Hoegh-Guldberg *et al.* 2007) and will soon approach conditions that have no precedent in the past 20 million years (Raven *et al.* 2005).

As you know, 450 ppm is an extremely ambitious target for stabilisation of carbon dioxide in the atmosphere. This, and the fact that global temperature at this point is almost 2°C above preindustrial temperatures, suggests that increases above 450 ppm are now very likely.

Coral reefs have been called the "canary in coal mine" for global ecosystems. While this might have been true 10 years ago, coral reefs are actually more akin to flocks of canaries with conditions for wetlands like Kakadu, reefs like the Great Barrier Reef, rainforests like Daintree, and Alpine Australia rapidly setting off major alarms.

These concerns are joined also by threats to the stability of the Greenland ice sheet. Our current understanding of these massive landlocked ice sheets is that an increase of carbon dioxide in the atmosphere beyond 450 ppm will put 3°C above the ice sheet. This is enough for the complete breakdown of these large bodies of water - a consequence that will be with us for thousands of years and will dramatically transform the earth.

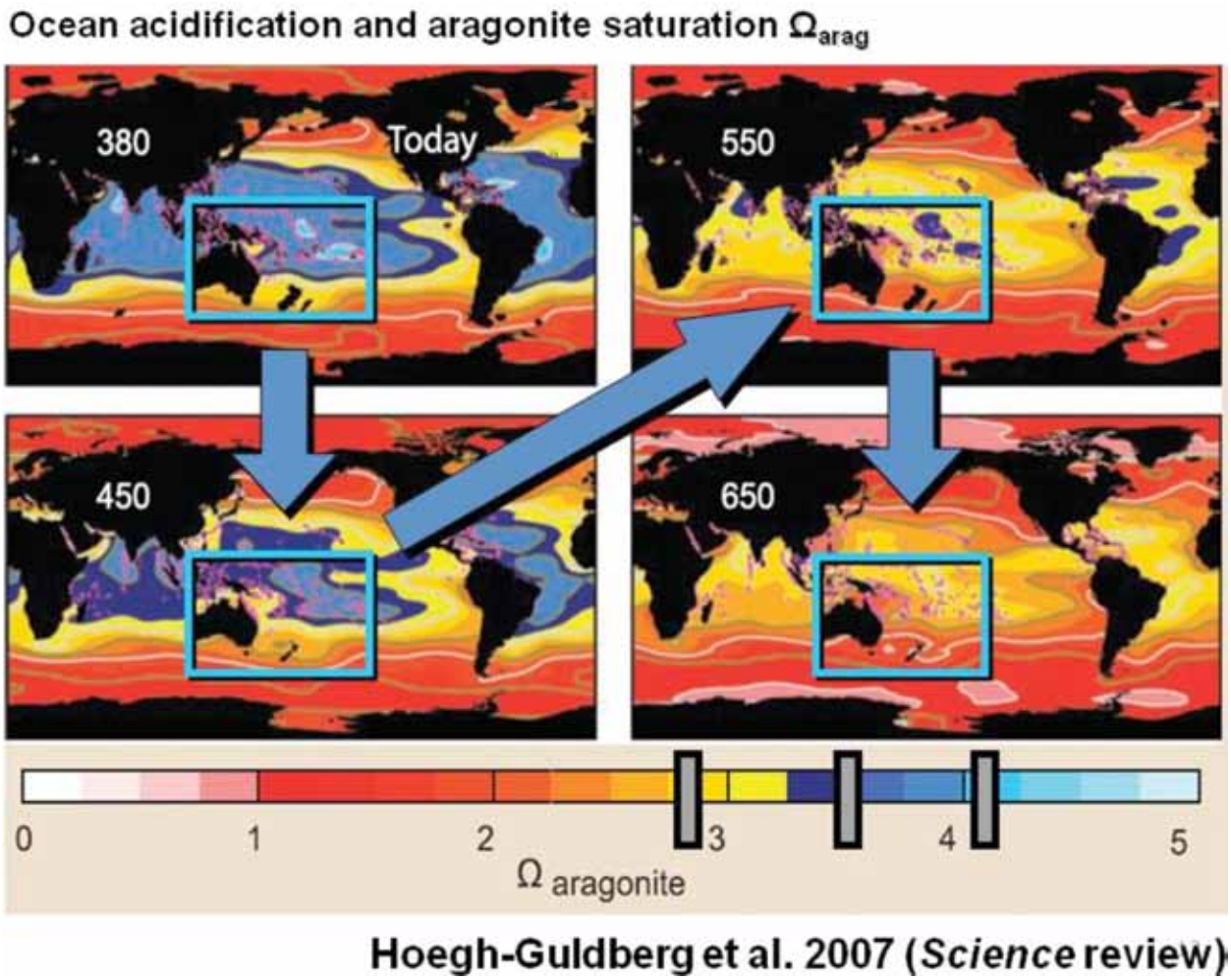

Figure 9: The aragonite saturation constant which is a measure of the availability of carbonate for coral calcification (Kleypas *et al.* 1999) as calculated for different carbon dioxide pressures in the atmosphere (numbers in the top left-hand corners). The blue colours represent concentrations above aragonite saturation of 3.3, which is the minimal saturation required for bicarbonate coral reef ecosystems.

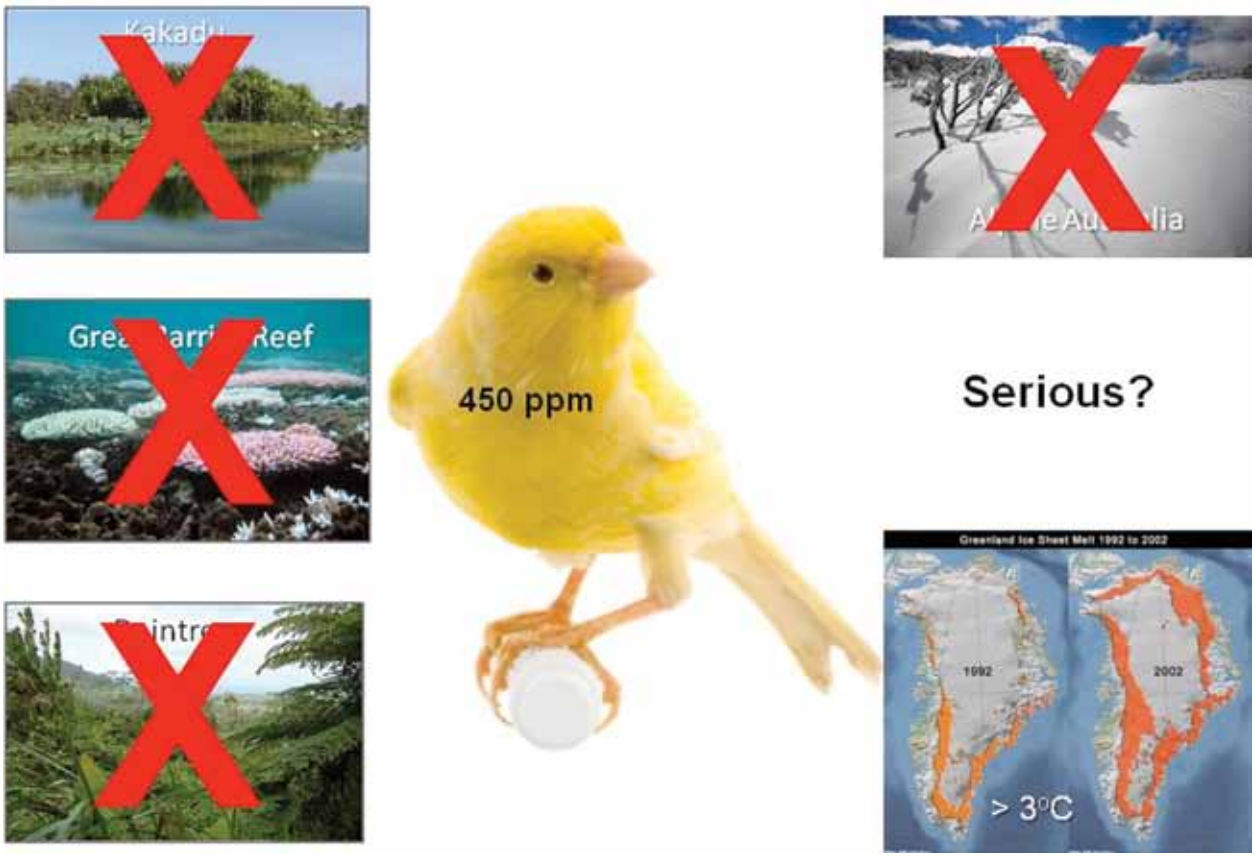

Figure 10. Canary in multiple coal mines.

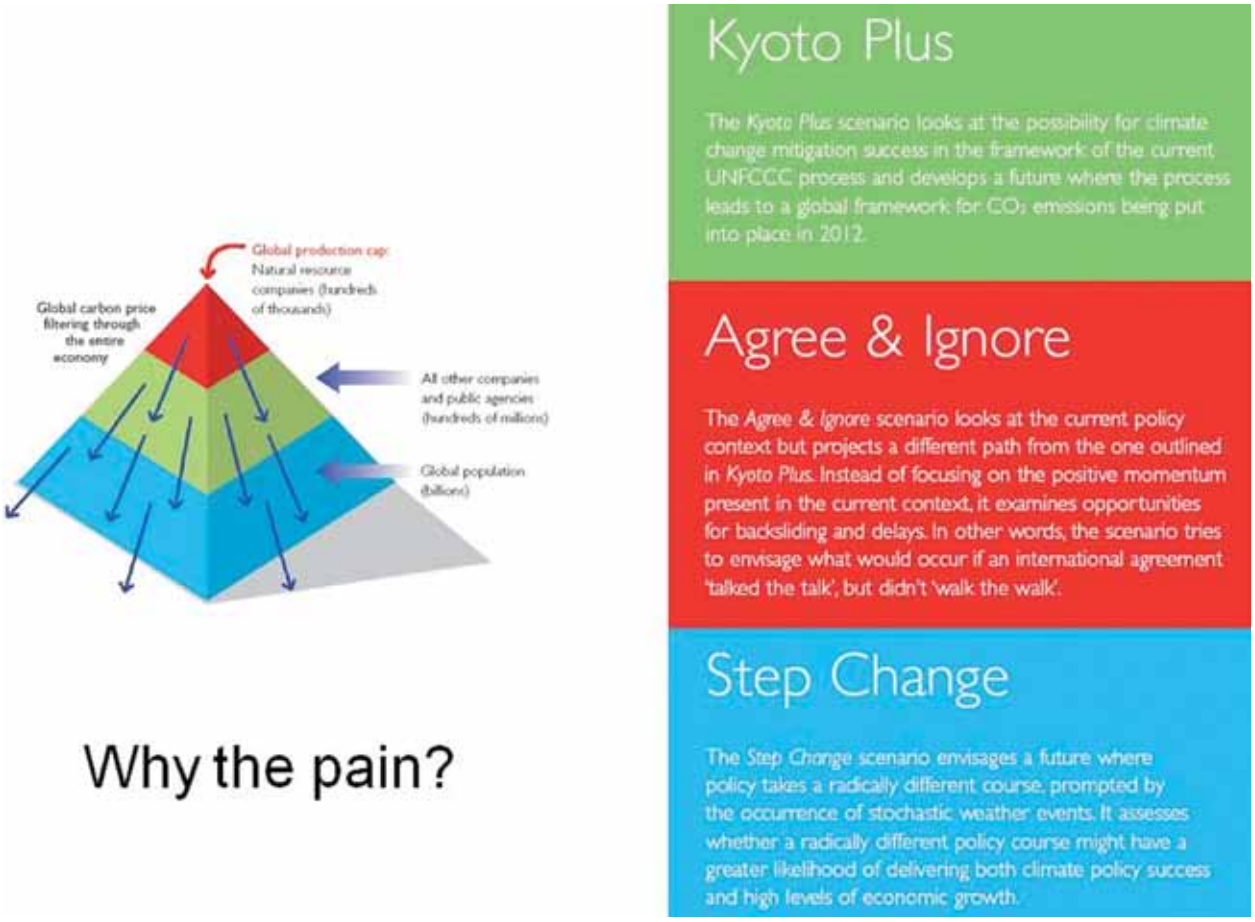

Figure 11: Three scenarios developed by the Stockholm Network for scenarios of how the world will unfold. http://www.stockholm-network.org.

These observations identify 450 ppm CO_2 as an absolutely critical number that we must not rise above. They also suggest that we should be in emergency mode and taking measures that would match the scale of this country-level and international crisis.

I want to finish with this Figure which comes from the Stockholm network, which is a European think tank that considers how the future might unfold. The document is worth reading and is located on the Stockholm network Web site. The think tank came up with three stages in the evolution of our response to climate change. I have rearranged their sequence from the network to a linear series, making some assumptions about how I think the world will unfold.

The first one is entitled "agree and ignore", and describes the current situation where scientific evidence like that I have presented today and which has been endlessly compiled in a convincing manner by the Intergovernmental Panel on Climate Change (IPCC) tells a very interesting and compelling story. Basically we had been told that a 2°C rise in global temperature will create enormous difficulties for both natural and human systems. The costs of these impacts dwarf any cost that we might pay today to avoid the problems of climate change in the future. However, we fail to act. This scenario recognizes the fact that lip service given to this story about the response can only be characterised as one in which the issue is essentially bought. This characterises the Howard and Bush governments.

The second scenario, entitled "Kyoto plus", correctly imagines a world in which Rudd, Obama and an energised world leadership head to Kyoto and forge the second phase of the Kyoto style agreements on emission control. As part of its agreement a deal is struck with developing countries such as India and China, in which these countries eventually join aggressive action on emissions (once they have achieved 'developed' status).

This, of course, is admirable but that does not achieve the desired outcome of stabilising carbon dioxide in the atmosphere at 450 ppm. Nonetheless, the world continues to rumble along until a series of tragedies engulf the world.

These tragedies are imagined to happen in about five year's time and involve:

- Scorching series of summers that stretch emergency services in Europe and result in large-scale mortalities among humans due to fires and heat stress.
- The Indian subcontinent is virtually washed away in a series of super monsoon seasons which see large-scale flooding and death in countries such as Bangladesh.
- Crops fail in Africa as extreme drought and temperatures sweep across the continent
- North America and Australia experiences extreme temperatures, storms and fires on an unprecedented scale.

These events spur leaders into action and we see a series of emergency meetings at the international level which are motivated by the realisation on a broad scale that the Earth is headed for extremely difficult times, and that frameworks to limit CO_2 emissions that are in existence today are not working.

This leads to the implementation of a 'production cap' (Figure 11). This is essentially a series of international agreements that enforce limits on the amount of fossil fuels and other activities that are permissible on the planet. This is top-down, extremely controversial but absolutely necessary if we are to survive a planetary crisis on a massive scale.

I want to finish with the final question - why the pain? I guess I'm asking why we are not listening to the consensus science and avoiding the future that will place enormous burdens and 'pain' on ourselves and future generations.

It seems that we have compiled the evidence and even taken what we know to be critical issues and made our judgements as conservative as they could be. We have communicated the evidence of massive change and the consequences of our current emission regime.

Despite getting much of the message in terms of science and those politicians that our conviction politicians, we remain stuck in the Stockholm Network's "Agree and Ignore" scenario, when in fact, we should be rapidly adopting the 'production cap' approach to energy use as quickly as possible.

In this regard, one is reminded of the timeless adage – 'a stitch in time saves nine'. Perhaps it should be rephrased as 'a stitch in time may save 9 billion'!

References

Bruno, J. F., and E. R. Selig, 2007. Regional decline of coral cover in the Indo-Pacific: timing, extent, and subregional comparisons. *PLoS ONE.* , **2,** e711.

Hoegh-Guldberg, O., and Coauthors, 2007. : Coral Reefs under rapid cimate change and ocean acidification. *Science*, **318,** 1737-1742.

Kleypas, J. A., and C. Langdon, 2006.: Coral reefs and changing seawater chemistry, Chapter 5 *Coral Reefs and Climate Change: Science and Management. AGU Monograph Series, Coastal and Estuarine Studies*, J. Phinney, O. Hoegh-Guldberg, J. Kleypas, W. Skirving, and A. E. Strong, Eds., Geophys. Union, 73-110.

Kleypas, J. A., J. W. McManus, and L. A. B. Meñez, 1999: Environmental limits to coral reef development: Where do we draw the line? *American Zoologist*, **39,** 146-159.

Raven, J., et al. 2005. Ocean acidification due to increasing atmospheric carbon dioxide. *Royal Society Special report, London UK.*

Wilson, S. K. et al. 2006. Multiple disturbances and the global degradation of coral reefs: are reef fishes at risk or resilient? *Glob Change Biol*, **12,** 2220-2234.