Will we leave the Great Barrier Reef for our children?

Dr Chris McGrath*

This research paper evaluates Australia's response to climate change using a case study of the likely impacts of climate change on the Great Barrier Reef (GBR). From an Australian and global perspective, severe damage to the GBR represents "dangerous climate change" on all three criteria of Article 2 of the UNFCCC: not allowing ecosystems to adapt naturally; threatening food production; and unsustainable economic development. Australia recently ratified the Kyoto Protocol and has a national objective of reducing greenhouse emissions by 60% by 2050, compared with year 2000 levels. Australia has no stated goal for stabilising atmospheric greenhouse gases and global temperature rises but its emission reduction target is consistent with stabilising greenhouse gases between 450-550 ppm CO_2*-eq and stabilising global temperature rises between 2-3°C above pre-industrial levels. Such levels are likely to cause severe impacts to the GBR and marine ecosystems generally. Consequently, the current Australian policy response, as part of the global response, is failing to achieve sustainable development and is likely to lead to dangerous climate change.*

INTRODUCTION

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.[1] It is now a real question whether we will leave iconic natural wonders such as Australia's Great Barrier Reef (GBR) for our children. As Charlie Veron recently concluded:[2]

> We are now facing the inescapable conclusion that the GBR, along with all the other coral reefs in the world, will be diminished beyond anything we have ever considered "normal" as a direct result of human-induced climate change – and this will happen during the present century.

The purpose of this research paper is to evaluate the effectiveness of the Australian legal framework as part of the overall international response to address climate change using the GBR as a case study and "flagship ecosystem". While the Australian legal framework is based on a federal system of government in which power is divided

---

* BSc, LLB (Hons), LLM, PhD, Barrister-at-Law (Brisbane, Australia). Email: chris.mcgrath@envlaw.com.au. This paper is based on research under taken for a PhD available at http://www.envlaw.com.au/phd.pdf (viewed 3 March 2008). The law and facts are stated at 1 June 2008.

[1] Intergovernmental Panel on Climate Change (IPCC) [Parry ML, Canziani OF, Palutikof JP, van der Linden PJ and Hanson CE (eds)], *Climate Change 2007: Climate Change Impacts, Adaptatation and Vulnerability – Working Group II Contribution to the IPCC Fourth Assessment Report* (Cambridge University Press, Cambridge, 2007), p 44, available at http://www.ipcc.ch/ipccreports/ar4-wg2.htm (viewed 1 June 2008)

[2] Veron JEN, *A Reef in Time: The Great Barrier Reef from beginning to end* (Harvard University Press, London, 2008), p 226.

between the national government (known as the Australian, Commonwealth or Federal Government), six States, and two mainland Territories,[3] in practice the national government is driving the policy agenda for Australia's response to climate change. The focus here will, therefore, be on the national level response as part of the overall international response to climate change.

Evaluating the effectiveness of the legal framework in Australia to address climate change requires it to be assessed in terms of the likelihood that it will achieve its objective. This is because, in a legal context, "effectiveness" can be seen as a measure of how successful law is in solving the problem it was designed to address.[4] The overall objective of environmental law and policy is sustainable development. For climate change this objective has become avoiding "dangerous climate change" as defined in Article 2 of the *United Nations Framework Convention on Climate Change 1992* (UNFCCC):[5]

> The ultimate objective … is to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Evaluating the effectiveness of the international and Australian response to climate change is a significant research topic. Climate change is accepted as a global threat to ecosystem health and human society: the UNFCCC enjoys near universal membership, with 192 countries having ratified it.[6] Yet climate change is an extremely complex environmental policy problem for which achieving effective international and national responses is very difficult. Despite of this difficulty, evaluation of the effectiveness of the response to climate change is an essential part of good environmental policy processes within the policy cycle.[7] Robert Bartlett colourfully described such issues as "patently tangled, wicked environmental policy problems."[8] His 1994 comments about the need for improving environmental policy evaluation remain apt:[9]

> Programs, policies, processes, and institutions, particularly environmental ones, are messy things, and environmental policy evaluation must develop richer theories, concepts, and methodologies to provide useful information for further policymaking in spite of that messiness.

Evaluating the effectiveness of the protection of the GBR from climate change is a particularly significant research topic for several reasons. It is significant firstly because of the vulnerability of coral reefs to climate change and their economic, social and ecological value. The health of the GBR is particularly significant due to its iconic

---

[3] See generally, Bates G, *Environmental Law in Australia* (6th ed, Butterworths, Sydney, 2006); Fisher DE, *Australian Environmental Law* (Lawbook Co, Sydney, 2003).

[4] Zaelke D, Kaniaru D, and Kružíková E (eds), *Making Law Work - Environmental Compliance & Sustainable Development* (Cameron May Ltd International Law Publishers, London, 2005), p 22.

[5] Done at New York on 9 May 1992. Entry into force for Australia and generally, 21 March 1994. 31 ILM 849; ATS 1994 No 2. Available at http://unfccc.int/resource/docs/convkp/conveng.pdf (viewed 1 June 2008).

[6] See http://unfccc.int/essential_background/convention/items/2627.php (viewed 1 June 2008).

[7] See generally, Dovers S, *Environment and Sustainability Policy: Creation, Implementation, Evaluation* (The Federation Press, Sydney, 2005).

[8] Bartlett R, "Evaluating Environmental Policy Success and Failure" in Vig N and Kraft M (eds), *Environmental Policy in the 1990s - Towards a New Agenda* (2nd ed, CQ Press, Washington, 1994).

[9] Bartlett, n 8, p 183.

status as one of the most outstanding and well-known World Heritage properties. It is the largest system of coral reefs in the world with an area of about 350,000 km^2 and approximately 2,900 reefs. It is one of the world's richest areas of biological diversity and is generally regarded as one of the best managed coral reef systems in the world.[10]

RESEARCH DESIGN

This paper adopts the research methodology and philosophy of Colin Robson's "real world enquiry".[11] Robson points out that "one of the challenges inherent in carrying out investigations in the 'real world' lies in seeking to say something sensible about a complex, relatively poorly controlled and generally 'messy' situation."[12] This general point reflects Bartlett's colourful description of the difficulty of evaluating environmental policy. A "scientific attitude" is adopted here in that the research is carried out systematically, sceptically and ethically for the purpose of seeking the "truth" about the subject of the research.[13] It involves applied research because the interest here is on solving problems rather than just gaining knowledge.

In considering the research design, the purpose of the research undertaken here is to evaluate the effectiveness of the international and Australian policy response to climate change. The broad theoretical frameworks within which the research is undertaken are Policy Analysis[14] and Evaluation Theory.[15] Within these broad theoretical frameworks, the pressure-state-response (PSR) method of State of the Environment Reporting is used as the conceptual framework for evaluating the effectiveness of environmental policy in an integrative, holistic manner.[16] Figure 1 provides a diagram of the pressure-state-response model.

The OECD developed the PSR model in the early 1990s to structure its work on environmental reporting and it is based on the concept of causality.[17] Within this conceptual model, human activities that impact on the environment are "pressures" (e.g. greenhouse gas emissions). The physical condition of the environment and trends in this condition are the "state" or "condition" (e.g. mean global temperature). How society addresses these pressures and changes in the state of the environment is the "response" (e.g. international agreement of the UNFCCC). The PSR model is not the only conceptual approach to reporting on the state of the environment[18] and its

---

[10] Wilkinson C (ed), *Status of the Coral Reefs of the World* (Australian Institute of Marine Science, Townsville, 2004).

[11] Robson C, *Real World Research: A Resource for Social Scientists and Practitioner - Researchers* (2nd ed, Blackwell Publishers, Oxford, 2002).

[12] Robson, n 11, p 4.

[13] Robson, 11, p 18.

[14] See generally, Dovers, n 7.

[15] See generally, Robson, n 11, Ch 7; Patton MQ, *Utilization-Focused Evaluation: The New Century Text* (3rd ed, Sage Publications, USA, 1997); Rossi PH, Lipsey MW, Freeman HE, *Evaluation : A Systematic Approach* (7th ed, Sage Publications, Thousand Oaks, 2004); and Alkin MA (ed), *Evaluation Roots: Tracing Theorists' Views and Influences* (Sage Publications, Thousand Oaks, 2004); McDavid JC and Hawthorn LRL, *Program Evaluation & Performance Measurement: An Introduction to Practice* (Sage Publications, Thousand Oaks CA, 2006).

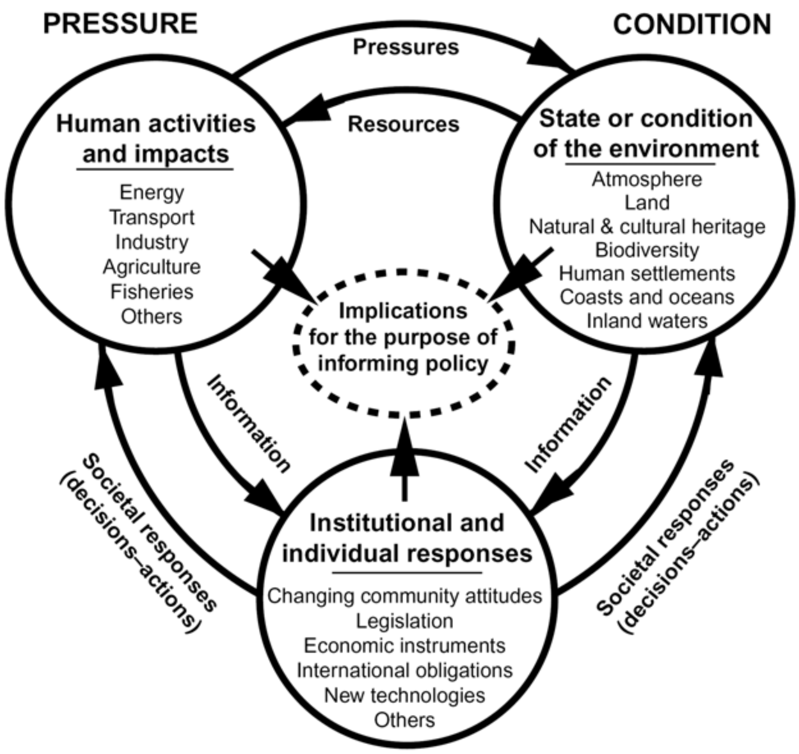
[16] See generally, Rump P, *State of the Environment Reporting: Source Book of Methods and Approaches* (UNEP/DEIA, Nairobi, 1996).

[17] See Rump, n 16.

[18] Compare, e.g., the drivers-pressures-state-impacts-responses (DPSIR) framework used in the UNEP, *Global Environment Outlook 4 (GEO-4)*, (UNEP, Nairobi, 2007), pp xxi-xxiii, available at http://www.unep.org/geo/geo4/media/index.asp (viewed 1 June 2008).

simplicity should not obscure the complexity of the issues it is used to address. However, it is the simplest, most systematic, comprehensive and meaningful framework with the greatest predictive power for evaluating the effectiveness of the response to human-induced environmental degradation currently available.[19]

Figure 1: Diagram of the pressure-state-response model[20]



Using the PSR model as an overall conceptual framework, the research question addressed in this paper is whether the international and Australian response to climate change will achieve sustainable development and avoid dangerous climate change? The hypothesis tested is that the current response to climate change will achieve sustainable development and avoid dangerous climate change.

The main research method used is a case study of the international and Australian laws and polices protecting the GBR from climate change. The case study provides factual information and examples to allow the hypothesis to be tested in the real world. The purpose of the case study is, "to tell a big story through the lens of a small case."[21] The ecological, social, and economic value of the GBR ecosystem for Australia and globally, and its apparent vulnerability to climate change, make it a suitable case study to address the research question.

---

[19] See McGrath C, "How to evaluate the effectiveness of an environmental legal system" (PhD thesis, Queensland University of Technology, Brisbane, 2007), available at http://www.envlaw.com.au/phd.pdf (viewed 1 June 2008).

[20] Australian State of the Environment Committee, *Australia State of the Environment 2001* (CSIRO Publishing, Melbourne, 2001), p 115, available at http://www.environment.gov.au/soe/ (viewed 1 June 2008).

[21] Tan W, *Practical Research Methods* (2nd ed, Prentice Hall, Singapore, 2004), p 77.

The sampling strategy used for the case study is a review of published literature, including major scientific reports, and laws and policies relevant to the case study. No primary research is conducted, for example on the impacts of climate change on coral reefs. The pressure of anthropogenic greenhouse gas emissions and the trends in the condition of the atmosphere can be understood from reviewing relevant science on climate change. This provides the factual basis for evalulating the likely effectiveness of current laws and policies in achieving sustainable development and avoiding dangerous climate change.

PRESSURE

Climate change

Global temperatures, and hence the Earth's climate, are closely linked with the concentration of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere.[22] Increasing concentrations of greenhouse gases trap greater heat in the atmosphere causing a warming effect. For at least the past 650,000 years prior to the Industrial Revolution the concentration of CO_2 in the atmosphere varied between 180 and 300 parts per million (ppm).[23] Since the Industrial Revolution, globally averaged concentrations of CO_2, the major greenhouse gas in the atmosphere, have increased dramatically beyond the upper threshold of natural fluctuation for the past 650,000 years primarily due to anthropogenic emissions of greenhouse gases from the combustion of fossil fuels, agriculture, and land-use changes.

The Intergovernmental Panel on Climate Change (IPCC), the world's leading scientific body on climate change, released its Fourth Assessment Report in 2007. It concluded that mean global surface temperatures have increased by 0.74 ± 0.18°C in the past 100 years and that most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.[24] Figure 2 shows the IPCC's best estimates of equilibrium temperature increases for different levels of greenhouse gases and aerosols in the atmosphere, measured in carbon dioxide equivalents (CO_2-eq).

---

[22] See generally Pittock AB, *Climate Change: Turning Up the Heat* (CSIRO Publishing, Melbourne, 2005); and Houghton J, *Global Warming: The Complete Briefing* (3rd ed, Cambridge University Press, Cambridge, 2004).

[23] Petit JR, Jouzel J, Raynaud D, Barkov NI, Barnola JM, Basile I, Bender M, Chappellaz J, Davis M, Dalaygue G, Delmotte M, Kotlyakov VM, Legrand M, Lipenkov VY, Lorius C, Péplin L, Ritz C, Saltzman E, and Stievenard M, "Climate and atmosphere history of the past 420,000 years from the Vostok ice core, Antarctica" (1999) 399 *Nature* 429; and Siegenthaler U, Stocker TF, Monnin E, Lüthi D, Schwander J, Stauffer DR, Barnola JM, Fisher H, Masson-Delmotte V, and Jouzel J, "Stable Carbon Cycle – Climate Relationship During the Late Pleistocene" (2005) 310 *Science* 1313.

[24] IPCC [Solomon SD, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, and Miller HL (eds)], *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC* (Cambridge University Press, Cambridge, 2007), p 5. Available at http://www.ipcc.ch/ipccreports/ar4-wg1.htm (viewed 1 June 2008).

Figure 2: IPCC best guess of mean global temperature rises for different concentrations of atmospheric greenhouse gases in carbon dioxide equivalents[25]

Equivalent CO_2	Best guess
350	1.0
450	2.1
550	2.9
650	3.6
750	4.3
1,000	5.5
1,200	6.3

Atmospheric concentrations of greenhouse gases and aerosols have already passed 350 ppm CO_2-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 CO_2 reached 379 ppm in 2005 and was increasing by around 2 ppm per year.[26] Including the effect of other greenhouse gases such as methane, the total concentration of atmospheric greenhouse gases was around 455 ppm CO_2-eq (range: 433–477 ppm CO_2-eq) in 2005.[27] However, the cooling effects of aerosols and landuse changes reduce radiative forcing so that the net forcing of human activities was in the range of 311 to 435 ppm CO_2-eq, with a central estimate of about 375 ppm CO_2-eq for 2005.[28] The current growth in CO_2 emissions from the burning of fossil fuels exceeds even the "worst case" IPCC projections.[29]

Compounding the difficulty of stabilising greenhouse gases and aerosols around 350 ppm CO_2-eq to attempt to keep global temperature rises beneath 1°C are the facts that, even if emissions are dramatically reduced, natural processes in the Carbon Cycle will be slow to remove the current levels of CO_2 from the atmosphere. Following perturbation of the natural Carbon Cycle about 50% of an increase in atmospheric CO_2 will be removed within 30 years, a further 30% will be removed within a few centuries and the remaining 20% may remain in the atmosphere for many thousands of years.[30]

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 3 shows

---

[25] IPCC, n 24, Table 10.8, p 826.
[26] IPCC, n 24, pp 2 and 137.
[27] IPCC [Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA (eds)], *Climate change 2007: Mitigation. Contribution of Working group III to the Fourth Assessment Report of the IPCC* (Cambridge University Press, Cambridge, 2007), p 102. Available at http://www.ipcc.ch/ipccreports/ar4-wg3.htm (viewed 1 June 2008).
[28] IPCC, n 27, p 102.
[29] 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 (viewed 20 December 2007).
[30] IPCC, n 27, p 514.

the results of IPCC modelling for six stabilisation scenarios and the corresponding reductions in greenhouse gas emissions required globally by 2050.

Figure 3: IPCC stabilisation scenarios[31]

Stabilisation scenarios	Concentration of greenhouse gases (ppm CO_2-e)	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

It is significant to note that the IPCC has not modelled emission reduction scenarios that it expects will stabilise global temperatures rises less than 2°C. A global mean temperature rise of 2°C is the lowest modelled stabilisation regime, requiring a reduction in global greenhouse gas emissions of 85% by 2050 compared with 2000 levels. It is unclear from the text itself why this approach has been taken but it may reflect a conclusion by the IPCC that stabilisation at less than a global mean temperature rise of 2°C is no longer practicable.

Likely impacts of climate change on coral reefs

Coral reefs dominate coastal tropical environments between the latitudes 25°S and 25°N and roughly coincide with water temperatures between 18°C and 30°C.[32] Corals appear to be living only 1-2°C below their upper thermal limit at which bleaching occurs and an additional ~1°C in maximum sea temperatures results in mortality.[33]

Rising water temperatures and extreme heat events in summer months are now evident on the GBR and expected to increase in the future due to climate change. Average sea surface temperatures of the GBR for the most recent 30 years (1976 to 2005) are 0.4°C warmer than the earliest instrumental 30 years (1871 to 1900).[34]

---

[31] Adapted from IPCC n 27, Table 3.5, p 198; and IPCC [Pachauri RK and Reisinger A (eds)], *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC, Geneva, 2007), Table 5.1, p 67, available at http://www.ipcc.ch/ipccreports/ar4-syr.htm (viewed 1 June 2008).

[32] Hoegh-Guldberg O, "Coral bleaching, climate change and the future of the world's coral reefs" (1999) 50(8) *Mar. Freshw. Res.* 839 at 841.

[33] Lough J, Berkelmans R, van Oppen M, Wooldridge S, Steinberg C, "The Great Barrier Reef and Climate Change" (2006) (19) *Bull. Aust. Meteorological and Oceanographic Soc.* 53 at 54.

[34] Johnson JE and Marshall PA (eds), *Climate Change and the Great Barrier Reef: A Vulnerability Assessment* (GBRMPA, Townsville, 2007), p 34, available at http://www.gbrmpa.gov.au/corp_site/info_services/publications/misc_pub/climate_change_vulnerability_assessment/climate_change_vulnerability_assessment (viewed 7 October 2007).

Climate change is expected to have severe impacts on the GBR in coming decades and is accepted as a major threat to coral reefs worldwide.[35] It is expected to affect coral reefs predominantly through changes of three variables: increases in sea surface temperature causing coral bleaching; decrease in calcification rates by increased concentrations of carbon dioxide in the atmosphere changing seawater chemistry; and increases in sea level.[36]

Increases in sea surface temperatures causing coral bleaching is the most immediate threat from climate change. Coral bleaching occurs when water temperatures exceed their normal maximum extremes causing corals to expel their symbiotic algae, known as zooxanthellae, and turn a brilliant white colour.[37] "Coral bleaching" is used to describe this phenomenon because the normally colourful corals appear to have been bleached white. Corals may recover from mild coral bleaching events but severe events can cause widespread death of corals.[38] The immediate effects of severe coral bleaching causing widespread mortality of corals allowing colonisation of the substrate by algae and subsequent partial recolonisation by corals in the absence of further bleaching events are shown in the following series of photographs.

---

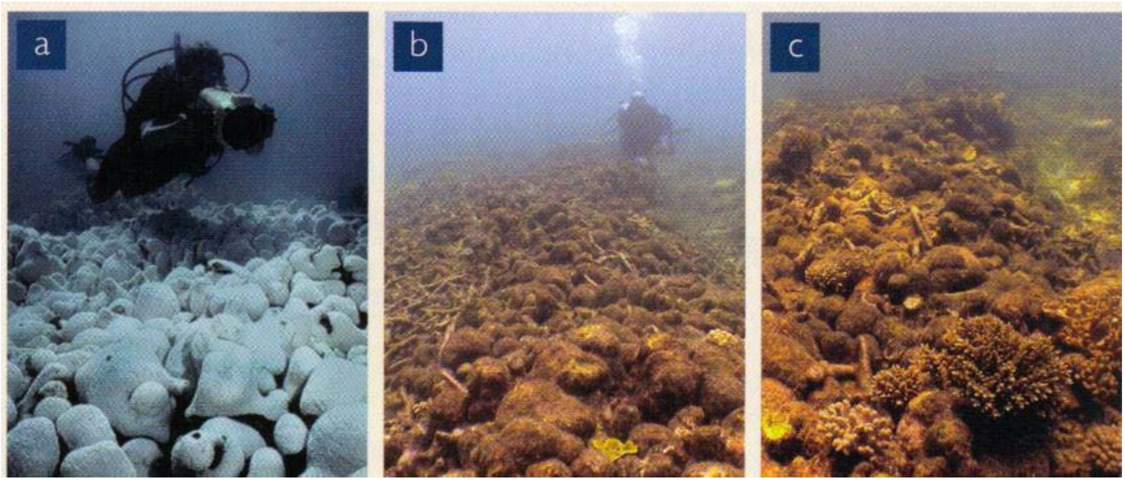
[35] Hoegh-Guldberg, n 32; Hughes TP, Baird AH, Bellwood DR, Card M, Connolly SR, Folke C, Grosberg R, Hoegh-Guldberg O, Jackson JBC, Kleypas J, Lough JM, Marshall P, Nyström M, Palumbi SR, Pandolfi JM, Rosen B, Roughgarden J, "Climate Change, Human Impacts, and the Resilience of Coral Reefs" (2003) 301 *Science* 929; Done T, Whetton P, Jones R, Berkelmans R, Lough J, Skirving W, and Wooldridge S, *Global climate change and coral bleaching on the Great Barrier Reef* (DNR, Brisbane, 2003), available at: http://www.nrw.qld.gov.au/science/pdf/barrier_reef_report_1.pdf; Hoegh-Guldberg O and Hoegh-Guldberg H, *The implications of climate change for Australia's Great Barrier Reef* (WWF Australia, Sydney, 2004), available at http://wwf.org.au/news/n65/; Wilkinson, n 10, Ch 11; Grimsditch GD and Salm RV, *Coral Reef Resilience and Resistance to Bleaching* (IUCN, Gland, 2005), available at http://www.iucn.org/themes/marine/pdf/coral_reef_resilience_gg-rs.pdf; Hoegh-Guldberg O, "Low coral cover in a high-CO_2 world" (2005) 110 *J. Geophys. Res*. C09S06; Donner SD, Skirving WJ, Little CM, Oppenheimer M, Hoegh-Guldberg O, "Global assessment of coral bleaching and required rates of adaptation under climate change" (2005) 11 *Global Change Biology* 2251; Johnson and Marshall, n 34; and the Reef Futures website at http://www.reeffutures.org/topics/bleach/cause.cfm.

[36] Reviewed in Hoegh-Guldberg O, Anthony K, Berkelmans R, Dove S, Fabricus K, Lough J, Marshall P, van Oppen MJH, Negri A and Willis B, "Vulnerability of reef-building corals on the Great Barrier Reef to climate change", Ch 10 in Johnson and Marshall (eds), n 34, p 295 (citations omitted).

[37] Several other factors, such as changes in salinity and some toxins, may also cause coral bleaching but are not relevant to the present discussion. See Hoegh-Guldberg et al, n 36.

[38] Hoegh-Guldberg et al, n 36.

Figure 5: Coral bleaching and partial recolonisation by corals[39]



1998 **2002** **2004**

Heidi Schuttenberg and Paul Marshall explained the sequence of photographs as follows:

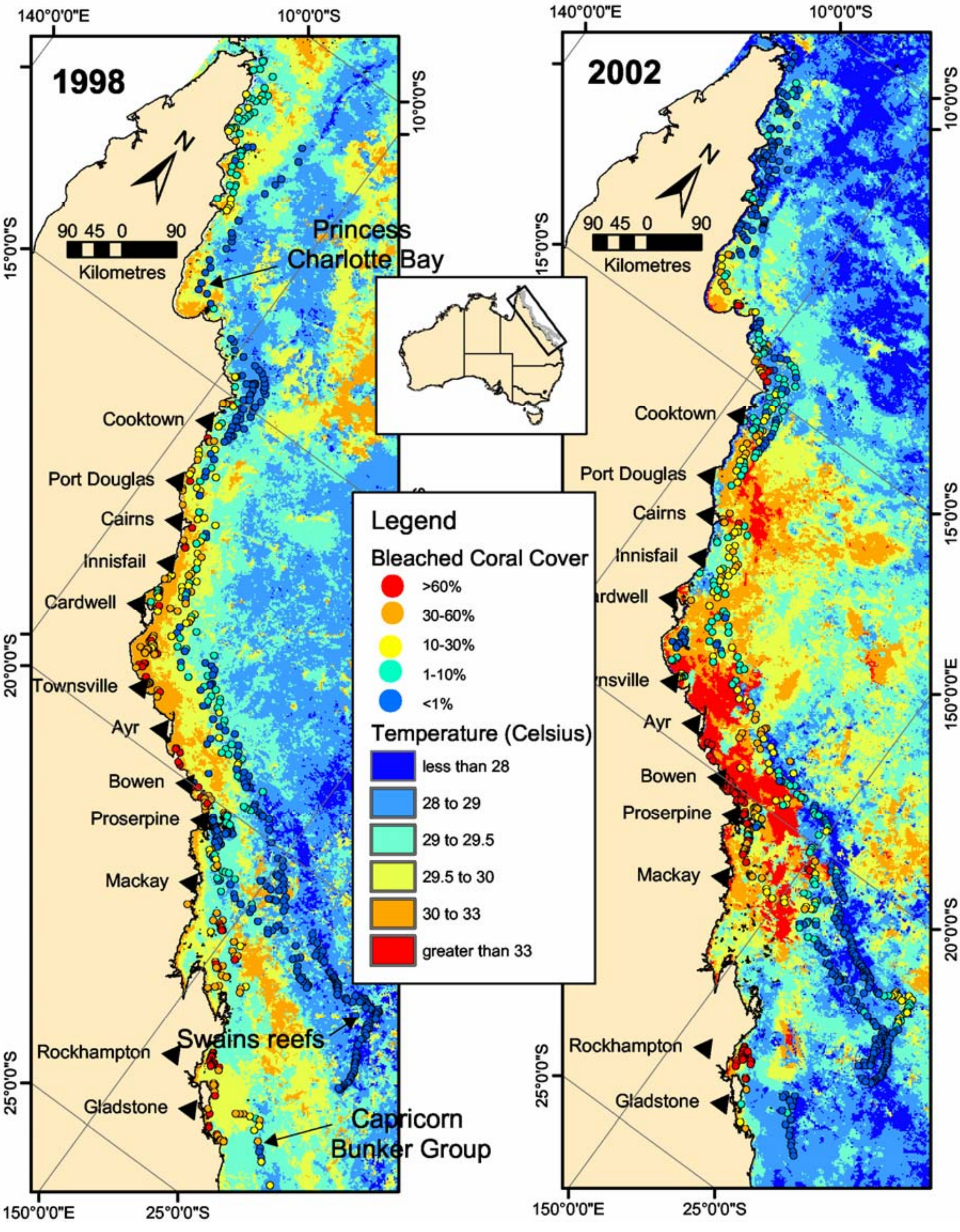
> Photos of the reef at Pelorus Island [Palm Island Group, offshore from the Cardwell-Hinchinbrook Region] on the Great Barrier Reef during and after severe bleaching-induced mortality. (a) This large stand of *Goniopora*, or daytime coral, was completely bleached during the summer of 1998. It died shortly after. (b) Despite healthy conditions and effective control of algae by herbivores, only the earliest stages of recovery were evident by 2002. (c) There was good coral recruitment by 2004, but full recovery is likely to take decades.

The coral bleaching event in 1998 on Pelorus Island shown in photograph (a) was part of a mass coral bleaching event across the globe. In that year coral bleaching due to extreme water temperatures effectively destroyed 16% of the coral reefs of the world, with losses in the Indian Ocean of almost 50%.[40] These impacts are unprecedented in the evolutionary history of the GBR or globally. The recent mass mortality of Caribbean reef corals dramatically altered reef community structure in a manner that is unprecedented for at least 95,000 years.[41]

There have been two major coral bleaching events on the GBR, in 1998 and 2002.[42] Ray Berkelmans and his colleagues analysed the 1998 and 2002 events and found that spatial patterns of bleaching were similar in both years and that short periods of high water temperature are highly stressful to corals and result in highly predictable bleaching patterns.[43] Figure 6 shows the results of the survey of coral bleaching and maximum sea surface temperatures in 1998 and 2002.

[39] Schuttenberg H and Marshall P, *A Reef Manager's Guide to Coral Bleaching* (GBRMPA, Townsville, 2006), p 12.
[40] Wilkinson, n 10, p 22.
[41] Pandolfi JM and Jackson JBC, "Ecological persistence interrupted in Caribbean coral reefs" (2006) 9 (7) *Ecology Letters* 818.
[42] Johnson and Marshall, n 34.
[43] Berkelmans R, De'ath G, Kininmonth S, and Skirving WJ, "A comparison of the 1998 and 2002 coral bleaching events on the GBR: spatial correlation, patterns and predictions" (2004) 23 (1) *Coral Reefs* 74.

Figure 6: Raw aerial survey results of coral bleaching in 1998 and 2002 overlaid on the maximum 3-day sea surface temperature for every pixel during the warmest months of the austral summer (December-March)[44]



Berkelmans and his colleagues found in 1998, 42% of reefs were bleached to some extent with 18% strongly bleached. In 2002, 54% of reefs were bleached to some extent with 18% strongly bleached. There was a close correlation between coral bleaching and

[44] Berkelmans, De'ath, Kininmonth, and Skirving, n 43, p 77.

maximum sea surface temperature. Modelling the relationship between the bleaching events and maximum sea surface temperature:[45]

> … indicates that a 1°C increase [in maximum sea surface temperature over a 3 day period] would increase the bleaching occurrence of reefs from 50% (approximate occurrence in 1998 and 2002) to 82%, while a 2 °C increase would increase the occurrence to 97% and a 3 °C increase to 100%. These results suggest that coral reefs are profoundly sensitive to even modest increases in temperature and, in the absence of acclimatization/adaptation, are likely to suffer large declines under mid-range International Panel for Climate Change predictions by 2050.

Ove Hoegh-Guldberg found the size of a thermal anomaly and the time that corals are exposed to it in Degree Heating Weeks or Months ("DHM") can give a fairly accurate projection of the outcome of exposure of corals to stress.[46] He assumed, based on previous studies, that bleaching begins for corals exposed to DHM values of 0.5 of more. This is equivalent to two weeks exposure to a +1°C anomaly above long term sea temperatures. Severe mortality events begin when corals are exposed to DHM values equal to or greater than 3.2. This is equivalent to more than 9 weeks at +1°C anomaly above long-term sea temperatures at each site, or 4.5 weeks at +2°C anomaly above long-term sea temperatures at each site, and so on. Using the IPCC "business as usual" scenario for future greenhouse emissions, Hoegh-Guldberg found:[47]

> If the projected increases in sea temperature follow the trajectory suggested by the [IPCC], reefs should soon start to decline in terms of coral cover and appearance. With a doubling of CO_2, thermal stress levels will soon reach the levels seen at isolated yet catastrophically affected sites in 1998. When these conditions arrive on reefs on the Great Barrier Reef more than three times per decade, coral cover should have declined to near zero. These dates are on average around 2030-2040 for southern, central and northern sectors of the Great Barrier Reef.

Hoegh-Guldberg noted that a key observation regarding heat stress in reef-building corals is that not all corals are equally sensitive to temperature.[48] Corals with thicker tissues and more massive growth forms tend to be more tolerant than corals that have thinner tissues and branching growth forms. The thermal threshold above which corals and their symbionts will experience heat stress and bleaching also varies geographically, indicating that corals and zooxanthellae have evolved over evolutionary time to local temperature regimes. Corals closer to the equator have thermal thresholds for bleaching that may be as high as 31°C while those at higher latitudes may bleach at temperatures as low as 26°C. Thresholds may also vary seasonally. However, Hoegh-Guldberg concluded that, while there is some variability in the impact of climate change according to latitude and proximity to the Queensland coast, the differences are small and delays in response to warming due to these factors are at most a couple of decades.[49]

This body of research has led to recent consensus statements from coral reef scientists on the multiple threats posed to coral reefs by climate change. The Third International Tropical Marine Ecosystem Management Symposium in Mexico in October 2006 and the International Coral Reef Initiative General Meeting held in Japan

---

[45] Berkelmans et al, n 43, pp 74 and 82; see also Done et al, n 35. Note: an increase in mean and variance increases the frequency of extremes: see Houghton, n 22, p 129.
[46] Hoegh-Guldberg, n 32; Hoegh-Guldberg and Hoegh-Guldberg, n 35, p 62.
[47] Hoegh-Guldberg and Hoegh-Guldberg, n 35, p 66.
[48] Hoegh-Guldberg, n 32; Hoegh-Guldberg and Hoegh-Guldberg, n 35, p 37.
[49] Hoegh-Guldberg and Hoegh-Guldberg, n 35, p 72.

in April 2007 stated that the actions required to support reef resilience to climate change include:[50]

> Limit climate change to ensure that further increases in sea temperature are limited to 2°C above preindustrial levels and ocean carbonate ion concentrations do not fall below 200 mol. kg^{-1}.

The IPCC also concluded that climate change is a major threat to coral reefs worldwide, including the GBR. Specifically in relation to Australia and New Zealand, it found that there is a very high confidence that, "significant loss of biodiversity is projected to occur by 2020 in some ecologically-rich sites including the Great Barrier Reef and Queensland Wet Tropics."[51] It found, when considering the impacts of climate change on coastal systems, there is very high confidence that:[52]

> Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1 to 3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals.

Hoegh-Guldberg and his colleagues concluded in a recent, major review of the likely impacts of climate change to the GBR:[53]

> The vulnerability of coral and the reefs they build to climate change was bought into sharp focus after 1998, when an estimated 16 percent of the world's coral communities died. Analysing the literature since that time reveals that rapidly rising sea temperatures and increasing levels of acidity in the ocean remain the major threat to coral reefs. 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, coupled with the additional vulnerability of coral reefs to high levels of acidification once the atmosphere reaches 500 parts per million, suggests that coral dominated reefs will be rare or non-existent in the near future.

In relation to the potential for thermal adaptation and acclimatization noted by the IPCC, there is evidence that adult corals, at least in some circumstances, are capable of limited acclimatization or adaptation to increased water temperatures;[54] however, there is not a strong case for adaptation playing a role in modifying the thermal tolerances of the reef-building corals to keep pace with the expected rate of water temperature increase due to climate change.[55] The widespread coral bleaching events in 1998 and 2002 suggest that adaptation by corals will not avoid, at least, severe short to medium-term impacts of rising sea temperatures.

The potential for corals to keep pace with climate change by adapting to higher water temperatures is also likely to be limited by the fact that, as noted above, increase in temperature is not the only impact of climate change on coral reefs. Hoegh-Guldberg

---

[50] Available, respectively, at http://www.itmems.org/Coral_Reefs_Climate_Change.pdf and http://www.icriforum.org/library/Reso_CC_Tokyo_0407.pdf (viewed 30 October 2007). See also the ARC Centre of Excellence for Coral Reef Studies, "Consensus Declaration on Coral Reef Futures" at http://www.coralcoe.org.au/news_stories/communique.html (viewed 30 October 2007).

[51] IPCC, n 1, p 11.

[52] IPCC, n 1, p 9. "Very high confidence" is defined as "at least 9 out of 10 chance of being correct."

[53] Hoegh-Guldberg et al, n 36, p 295 (citations omitted).

[54] See Baker AC, "Flexibility and specificity in coral-algal symbiosis: diversity, ecology, and biogeography of *Symbiodinium*" (2003) 34 *Annu. Rev. Ecol. Syst.* 661; Berkelmans R and van Oppen MJH, "The role of zooxanthellae in the thermal tolerance of corals: a 'nugget of hope' for coral reefs in an era of climate change" (2006) 273 *Proc. R. Soc. Lond. B* 2305.

[55] Hoegh-Guldberg and Hoegh-Guldberg, n 35, pp 42-49; Hoegh-Guldberg (2005), n 35.

and his colleagues emphasised the importance of changes in seawater chemistry due to increasing carbon dioxide concentrations:[56]

> Doubling atmospheric CO_2 above the ocean will cause the carbonate concentration to decrease to approximately 200 micromol per kg, with temperature having a small influence. A carbonate concentration of 200 micromol per kg is critical in that the calcification of corals and many other organisms declines effectively to zero at carbonate concentrations around this value. This impact is made even more significant because coral reefs are a balance between calcification and erosion and hence calcification needs to be well above zero to avoid a net erosion of coral reefs. There is overwhelming evidence that corals and the reefs they build will not be able to maintain themselves or grow if CO_2 concentrations rise above 500 parts per million. This level of CO_2 is at the lower end of the range of greenhouse scenarios for the end of this century.

Hoegh-Guldberg and his colleagues concluded in relation to vulnerability and thresholds for extinction risk and irreversibility for coral reefs from climate change that:[57]

> As outlined above, 500 parts per million is the highest CO_2 concentration under which any semblances to the communities of corals we have today can survive. It is also the only scenario in which the climate will eventually stabilise. Above this point (500 parts per million), coral reefs will also change irreversibly and be lost for many thousands of years. To contemplate any higher CO_2 is untenable given the huge likelihood of such catastrophic events as runaway greenhouse effects and the flooding of the planet as the Greenland and Western Antarctic Ice Sheets melt. Even though 500 parts per million is seen as an ambitious greenhouse target, effects on ocean temperature and acidity will mean that coral calcification will decrease to 40 percent of today's value and major (1998 level) bleaching events will occur every 2 to 4 years.

Katherina Fabricius and her colleagues reached a similar conclusion in assessing vulnerability of coral reefs from climate change:[58]

> A dramatic loss in reef biodiversity appears inevitable at atmospheric CO_2 concentrations approaching 500 parts per million. Given that impacts on many other ecosystems also become extreme at 450 to 500 parts per million, limiting emissions to below this point is critical for coral reefs.

While improvements to coastal management may help reduce these impacts, based on current knowledge it is expected that the ecology of the GBR will change dramatically over the next decades due to climate change.[59] This indicates that climate change represents the most severe threat to the GBR in the immediate-medium term future.[60]

---

[56] Hoegh-Guldberg et al, n 36, p 285 (citations omitted). See also, Hoegh-Guldberg O, Mumby PJ, Hooten AJ, Steneck RS, Greenfield P, Gomez E, Harvell CD, Sale PF, Edwards AJ, Caldeira K, Knowlton N, Eakin CM, Iglesias-Prieto R, Muthiga N, Bradbury RH, Dubi A, and Hatziolos ME, "Coral reefs under rapid climate change and ocean acidification" (2007) 318 *Science* 1737.

[57] Hoegh-Guldberg et al, n 36, p 296 (citations omitted).

[58] Fabricius KE, Hoegh-Guldberg O, Johnson J, McCook L and Lough J, "Vulnerability of coral reefs of the Great Barrier Reef to climate change", Ch 17 in Johnson and Marshall (eds), n 34, p 596.

[59] See the authors cited in footnote n 35, and Wolanski E and De'ath G, "Predicting the impact of present and future human land-use on the Great Barrier Reef" (2005) 64 *Estuarine, Coastal and Shelf Science* 504.

[60] Miller I and Sweatman H, "Status of coral reefs in Australia and PNG in 2004", Ch 11 in Wilkinson, n 10, Vol 2, p 327; Johnson and Marshall, n 34.

STATE OF THE GBR

The GBR is considered one of the least-disturbed coral reef systems in the world with most of it still in a relatively good condition.[61] Coral cover is currently used as a principal indicator of the condition of the GBR.[62] Trends in coral cover can usually be explained by current impacts or the recovery from past impacts. Coral cover on midshelf and outer shelf reefs is dynamic and generally controlled by disturbances from the coral eating crown-of-thorns starfish, coral bleaching events, and cyclones. Coral cover on surveyed inshore reefs is generally low compared to midshelf and outer shelf reefs and in several GBR regions has decreased to very low levels.[63]

Average sea surface temperatures in the GBR is now 0.4°C warmer than since at least the mid-18th century and could be between 1-3°C warmer by 2100.[64] The rate of warming has increased over the past 30 years and the current rate of warming is now considered to be well over a degree per century.[65] In 1998 and 2002 the GBR suffered major coral bleaching events linked to increased maximum sea temperatures. In 1998, 42% of reefs were bleached to some extent with 18% strongly bleached and in 2002, 54% of reefs were bleached to some extent with 18% strongly bleached.[66]

The expected future trend for the condition of the GBR due to climate change and coral bleaching is very negative. Details of this trend were set out above in the discussion of pressures on the GBR. Using the IPCC "business as usual" scenario for future greenhouse emissions, Hoegh-Guldberg projected coral cover would decline to near zero in all sectors of the GBR by 2030-2040.[67] The IPCC also concluded there is a very high confidence that, "significant loss of biodiversity is projected to occur by 2020 [to] the Great Barrier Reef" due to climate change.[68]

RESPONSE TO CLIMATE CHANGE

The response to climate change has involved the international community and all levels of government in Australia. The principal international agreements for collective action to address climate change are the UNFCCC and the Kyoto Protocol. The Kyoto Protocol provides, amongst other things, binding targets for the reduction of greenhouse gas emissions by developed countries for 2008-2012.

After considerable delay and controversy, Australia ratified the Kyoto Protocol following the election of a new federal government in November 2007. Australia has a target of limiting its greenhouse gas emissions to 108% of its 1990 levels during 2008-2012 under the Kyoto Protocol. Principally through reductions in the rates of land

---

[61] See Wilkinson, n 10.
[62] Sweatman H, et al, "Long-term monitoring of the Great Barrier Reef: Status Report No 5" (Australian Institute of Marine Science, Townsville, 2001), p 106.
[63] Sweatman, n 62.
[64] Lough et al, 33, p 56.
[65] Hoegh-Guldberg O, "Great Barrier Reef" in UNESCO World Heritage Centre, *Case Studies on Climate Change and World Heritage* (UNESCO, Gland, 2007), pp 31-32 (available at http://whc.unesco.org, viewed 18 April 2007), citing Lough JM, "Sea Surface Temperatures on the Great Barrier Reef", a contribution to the *Study of Coral Bleaching, Final Report* (GBRMPA, Townsville, 1999).
[66] Berkelmans et al, n 43.
[67] Hoegh-Guldberg and Hoegh-Guldberg (2004), n 35, p 66.
[68] IPCC, n 1, p 11.

clearing, Australia is expected to nearly achieve this target. Australia's greenhouse gas emissions are projected to reach 603 million tonnes annually of greenhouse emissions over 2008–12, which is 109% of 1990 levels.[69]

The new Australian Government has been elected on a policy platform clearly recognising the need to address climate change but its detailed policy response has not yet emerged.[70] The State and federal governments have commissioned Professor Ross Garnaut to conduct a major review of the impacts of climate change on the Australian economy for the purpose of recommending medium to long-term policies and policy frameworks to improve the prospects for sustainable prosperity.[71] That review is due to be completed in mid-2008 and the new Australian Government has stated it will not proceed with detailed policy announcements before receiving the report. However, based on pre-election policies the government has committed to two far-reaching policies: establishment of a national emissions trading scheme by 2010 and reducing Australia's year 2000 greenhouse emissions by 60% by 2050. The government has not stated the overall global temperature rise that it considers should be avoided.

The policy response of the previous Australian Government, while now quickly becoming obsolete, is relevant here in the context of understanding and evaluating the effectiveness of Australia's policy response over the past 10 years. During this period, particularly following the mass coral bleaching event in 1998, climate change has been recognised as a major threat to coral reefs.

The previous government's policy response was almost entirely based upon non-legislative and non-regulatory programs loosely coordinated under the 1998 *National Greenhouse Strategy* with the aim of meeting Australia's Kyoto target. These programs have been summarised elsewhere.[72] They included, for example, the Low Emissions Technology Demonstration Fund, a A$500 million fund, over 15 years, that was a flagship initiative under the government's 2004 Energy White Paper, *Securing Australia's Energy Future*.[73] The fund supported the commercial demonstration of technologies that have the potential to deliver large-scale greenhouse gas emission reductions in the energy sector, such as "clean coal" initiatives. An example of a grant under the fund is a $60 million grant for the Gorgon CO_2 Injection Project which involves separating and capturing the CO_2 from the natural gas produced from the Gorgon fields off Western Australia. The CO_2 is proposed to be injected deep underground into a saline aquifer, capturing up to 3 million tonnes of CO_2 a year and making it the largest geosequestration project in the world.

In addition to entirely voluntary, non-legislative programs, the previous federal government had established a limited regulatory framework for greenhouse gas emissions. The UNFCCC is nominally incorporated into Australian domestic law. It is annexed, in whole, in Schedule 3E of the *Ozone Protection and Synthetic Greenhouse Gas Management Act* 1989 (Cth). That Act, however, focuses on ozone depleting substances and not greenhouse gas emissions contributing to climate change.

---

[69] Australian Greenhouse Office, *Tracking to the Kyoto Target: Australia's Greenhouse Emissions Trends 1990 to 2008-2012 and 2020* (AGO, Canberra, 2006), p 1.
[70] See the new departmental website at http://www.climatechange.gov.au/ (viewed 1 June 2008).
[71] See http://www.garnautreview.org.au/ (viewed 1 June 2008).
[72] McGrath C, "Setting climate change targets to protect the Great Barrier Reef" (2007) 24 EPLJ 182 at 188-189.
[73] Energy Task Force, *Securing Australia's Energy Future* (Australian Government, Canberra, 2004).

There are three pieces of Commonwealth legislation passed by the previous government of note in relation to greenhouse issues. First, the *Renewable Energy (Electricity) Act* 2000 (Cth) aims to reduce greenhouse gas emissions by imposing a Mandatory Renewable Energy Target (MRET), which requires electricity providers to source 2% of their energy from renewable sources.[74] The new government has a policy to increase this to 20% renewables by 2020.[75] Second, in addition to the MRET, the *Energy Efficiency Opportunities Act* 2006 (Cth) requires large energy using businesses to undertake and report publicly an assessment of their energy efficiency opportunities and one of the objects of that Act is to reduce greenhouse emissions. Third, the *National Greenhouse and Energy Reporting Act* 2007 (Cth) requires corporations producing greenhouse emissions or using energy over specified thresholds to report their emissions and energy usage from mid-2008. This legislation is intended to provide the stepping-stone for a national emissions trading scheme.

The centrepiece of the previous government's environmental laws, the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act), is largely silent on greenhouse gas emissions and climate change. Section 520(3)(k) of the EPBC Act allows for regulations to give effect to the UNFCCC but no regulations have been made for that purpose. Two decisions of the Federal Court indicate that greenhouse gas emissions are effectively not regulated under the Act as even projects involving extremely large emissions of greenhouse gases, such as major coal mines, are not considered by the government to have a significant impact on the matters protected by the EPBC Act in the context of total global greenhouse emissions.[76] The new government has indicated it will amend the Act to insert a greenhouse trigger, which should overcome this gap in the legislation.[77]

The Australian Government recognises and accepts the threat climate change poses to the GBR. The Great Barrier Reef Marine Park Authority (the GBRMPA), a statutory authority created by the Australian Government to oversee planning and management of the GBR, has established a Climate Change Response Program to better understand and respond to climate change threats, including coral bleaching.[78] The GBR Coral Bleaching Response Plan, which is part of the Climate Change Response Program, is implemented every summer to monitor and document coral bleaching as part of a global protocol for assessing and monitoring coral bleaching.[79] It uses a combination of satellite imagery, aerial surveys, underwater surveys, and community monitoring to determine the extent and severity of a coral bleaching event, and to understand the impacts on the GBR. The plan has three main components, an early warning system,

---

[74] A tax penalty is imposed for failing to achieve this target by the *Renewable Energy (Electricity) (Charge) Act* 2000 (Cth).

[75] See http://www.alp.org.au/download/now/071030_renewable_energy_policy___final.pdf (viewed 1 June 2008).

[76] *Wildlife Preservation Society of Queensland Proserpine/Whitsunday Branch Inc v Minister for the Environment & Heritage & Ors* [2006] FCA 736 (Dowsett J); *Anvil Hill Project Watch Association Inc v Minister for the Environment and Water Resources* [2007] FCA 1480 (Stone J).

[77] However, note the criticisms of such a trigger made by Macintosh M, "The greenhouse trigger: where did it go and what of its future?", Ch 4 in Bonyhady T and Christoff P (eds), *Climate Law in Australia* (The Federation Press, Sydney, 2007).

[78] See http://www.gbrmpa.gov.au/corp_site/info_services/science/climate_change. See also ReefTemp, a mapping product that provides information on coral bleaching risk for the GBR region, at http://www.cmar.csiro.au/remotesensing/gbrmpa/ReefTemp.htm (viewed 1 June 2008).

[79] See http://www.gbrmpa.gov.au/corp_site/info_services/science/climate_change/response_plan.html (viewed 1 June 2008).

bleaching assessment and monitoring, and a communication program. It is intended to enable the GBRMPA to:

- develop a system to forecast coral bleaching events;
- provide early warnings of a major coral bleaching event;
- measure the spatial extent and severity of mass coral bleaching events;
- assess the ecological impacts of mass coral bleaching events;
- involve the community in monitoring the health of the GBR;
- communicate and raise awareness about coral bleaching and climate change impacts on the GBR;
- provide information to evaluate the implications of coral bleaching events for management policy and strategies.

The threat of climate change has been used by the GBRMPA, in part, to justify reduction of other stresses to the GBR, such as declining water quality and overfishing, to support the natural resilience of the reef ecosystem to help it survive climate change.

In addition to these laws, programs and policies of the previous and new Australian Government, various State and Territory laws, programs and policies seek to address climate change. An important, legislative contribution made by the Queensland Government was to end broad-scale land clearing for agricultural development in 2006. In early 2004 the Queensland Government passed the *Vegetation Management and Other Legislation Amendment Act* 2004 (Qld), with a stated objective of reducing greenhouse emissions.[80] This aims to reduce greenhouse gas emissions due to vegetation clearing by 20-25 megatonnes per year by 2008.[81] This major change in the law has been a key to Australia reducing its greenhouse gas emissions almost within the targets set under the Kyoto Protocol for the 2008-2012 commitment period, but rises in energy use and transportation emissions mean that Australia will need to find further means of reducing emissions to meet its targets beyond this period.

State and Territory governments have largely adopted the Australian Government's policies on greenhouse gas reductions. Using the State of Queensland as an example because the GBR lies along its coast, the Queensland Government has announced a policy of reducing the State's greenhouse emissions by 60% by 2050 based on year 2000 levels.[82] The details of how this will be achieved have not yet emerged. Aside from reining in greenhouse emissions by regulating land-clearing and committing to a 60% reduction in emissions by 2050, the Queensland Government has adopted the policies of the previous Australian Government by relying on voluntary development of new technologies to lower emissions. The simple reason for this appears to be that Queensland's economy is heavily reliant on coal mining and coal-fired power stations. These are major sources of greenhouse gas emissions contributing to climate change yet controlling them may have serious adverse effects on the State economy. Queensland's approach is, therefore, to emphasise the need for new technologies, particularly "clean coal" technology, to reduced greenhouse emissions. There are no significant mandatory controls on coal mining or power generation in relation to greenhouse emissions. The Queensland Government has established the

[80] Section 3(1)(g) of the amended *Vegetation Management Act* 1999 (Qld).
[81] See Queensland Government, *State Policy for Vegetation Management* (May 2004). Available at http://www.nrm.qld.gov.au/vegetation.
[82] See the Queensland Government, *ClimateSmart 2050* policy, available at http://www.thepremier.qld.gov.au/news/initiatives/climate/index.shtm (viewed 1 June 2008).

Office of Climate Change and the Queensland Climate Change Centre of Excellence, now within the Environmental Protection Agency, for climate change science and policy.[83]

This concludes the description of the pressures on the GBR, the condition of the GBR and the response to these pressures and trends in conditions. The next section evaluates the effectiveness of the response to protecting the GBR.

EVALUATION OF EFFECTIVENESS

Effective policy

Given the scale and complexity of climate change, responding to it effectively presents an enormous challenge for government and society. Government policies cannot afford to move too far in front of public opinion or public acceptance. Policies are unlikely to be effective in the long-term unless they are generally efficient, cost-effective, equitable, politically acceptable, and "optimal".[84] Short term success at a cost that leads to long-term failure (perhaps by leading to a change of government and reversal of unacceptable policies) is not truly *effective*.

While the Australian Government is constrained in responding to climate change by what is politically acceptable, it is important to recognise that this is a double-edged sword for and against strong action on climate change. For instance, measures to protect the GBR are likely to have strong public support given its immense social, economic and environmental value to Australia. The GBR can therefore be used as a "flagship ecosystem" to garner public support for very strong action.

Setting targets

The topic of target setting for climate change policy has generated a large amount of literature, particularly since 2001, of which the work of Michael Oppenheimer is particularly outstanding.[85] The most widely adopted interpretation and target for avoiding dangerous climate change is that of the European Union: "to limit global warming to no more than 2°C above the temperature in pre-industrial times."[86] The target of "no more than 2°C" is a quantitative, and measurable, target.

However, as the focus here is on protecting the GBR, the discussion will be limited to what target is required to protect the GBR. Oppenheimer and Petsonk suggest the uneven regional distribution of impacts mean that levels of climate change that impact

[83] See http://www.climatechange.qld.gov.au/response/office.html (viewed 1 June 2008).

[84] See generally, Gunningham N and Grabosky P, *Smart Regulation: Designing Environmental Policy* (Oxford University Press, Melbourne, 1998), pp 26-27.

[85] See, for example, Oppenheimer M and Petsonk A, "Article 2 of the UNFCCC: Historical origins, recent interpretations" (2005) 73 *Climate Change* 195.

[86] There have been repeated EU resolutions to this effect. A recent one is the EU Environment Council Conclusion at its 2785th meeting, Brussels, 20 February 2007, available at http://europa-eu-un.org/articles/fr/article_6790_fr.htm (viewed 7 March 2007). Note that the reference period for change is important to consider. For instance, Corfee-Morlot J, Smith J, Agrawala S, and Franck T, "Long-term goals and post-2012 commitments: where do we go from here with climate policy?" (2005) 5(3) *Climate Policy* 251, discuss global mean temperature increases of 1-4°C "compared with 1990 levels". Global mean temperatures had risen by approximately 0.6°C by 1990. A reference period of 1900 or pre-industrial temperatures accounting for this 0.6°C rise is used here. Consequently, references to 1-3°C temperature rises in this thesis are compared with 1900 or pre-industrial levels.

severely on only one region might not be regarded as "dangerous climate change" for the purposes of Article 2 of the UNFCCC.[87] This wider debate is not necessary to address here.

When the conclusions of the IPCC are synthesised, it becomes clear that reductions of greenhouse emissions of 60% by 2050, such as proposed by the new Australian Government[88] and the Queensland Government,[89] are not likely to prevent serious damage to the GBR. 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 the GBR. If a developed country such as Australia achieves a reduction in emissions of 60% by 2050 it is unlikely that global emissions will meet this target. The new Australian Government does not have an express stabilisation target for global temperature rises but the emissions reductions target of 60% by 2050 appears to be based on stabilising global temperature rises around 3°C.[90]

The critical need to stabilise global mean temperatures at less than 2-3°C is clear from the work of Berkelmans and his colleagues, and Hoegh-Guldberg, noted earlier. Berkelmans' modelling of the relationship between the bleaching events and maximum sea surface temperature:[91]

> … indicates that a 1°C increase [in maximum sea surface temperature over a 3 day period] would increase the bleaching occurrence of reefs from 50% (approximate occurrence in 1998 and 2002) to 82%, while a 2 °C increase would increase the occurrence to 97% and a 3 °C increase to 100%.

As noted earlier Hoegh-Guldberg found that:[92]

> With a doubling of CO_2, thermal stress levels will soon reach the levels seen at isolated yet catastrophically affected sites in 1998. When these conditions arrive on reefs on the Great Barrier Reef more than three times per decade, coral cover should have declined to near zero. These dates are on average around 2030-2040 for southern, central and northern sectors of the Great Barrier Reef.

Hoegh-Guldberg and his colleagues found that:[93]

> 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, coupled with the additional vulnerability of coral reefs to high levels of acidification once the atmosphere reaches 500 parts per million, suggests that coral dominated reefs will be rare or non-existent in the near future.

These studies indicate that a doubling of the global warming effect of greenhouse gases and aerosols to 550 ppm CO_2-eq, allowing a probable rise of 3°C in mean global temperature, is far too high a target to set if the policy objective is to avoid severe damage to the GBR. Stabilizing greenhouse gas concentrations and aerosols at 450 ppm

---

[87] Oppenheimer and Petsonk, n 85, p 208.

[88] Based on the climate change policy stated by the new Australian Prime Minister, Kevin Rudd, in May 2007, available at http://www.alp.org.au/media/0507/speloo300.php (viewed 25 November 2007).

[89] Queensland Government, *ClimateSmart 2050: Queensland's Climate Change Strategy* (Queensland Government Department of Premier and Cabinet, Brisbane, 2007), p 1. Available at http://www.thepremier.qld.gov.au/news/initiatives/climate/index.shtm (viewed 25 June 2007).

[90] See Spratt D, "Is Labor's climate policy 'backed by the science'?" (Carbon Equity, Melbourne, 2007), available at http://www.carbonequity.info/docs/alppolicy.html (viewed 14 November 2007).

[91] Berkelmans et al, n 43, pp 74 and 82.

[92] Hoegh-Guldberg and Hoegh-Guldberg (2004), n 35, p 66.

[93] Hoegh-Guldberg et al, n 36, p 295 (citations omitted).

CO_2-eq and allowing a rise of 2°C also appears too high; however, it may be impossible to avoid exceeding this target because the global atmospheric concentrations of CO_2 is already over 379 ppm and the atmospheric concentration of CO_2 is currently rising by around 2 ppm each year. The current warming effect of greenhouse gases, aerosols and landuse changes was about 375 ppm CO_2-eq in 2005. This rises to around 455 ppm CO_2-eq in 2005 if the cooling effect of aerosols is removed.

Detlef van Vuuren and his colleagues recently suggested that, technically, stabilizing greenhouse concentrations at 650, 550, 450 ppm and, under specific assumptions, 400 ppm carbon dioxide equivalents is feasible from median IPCC baseline scenarios on the basis of known technologies.[94] They suggested that creating the right socio-economic and political conditions for mitigation is more important than any of the technical constraints.

Given the difficulties in the negotiations of the Kyoto Protocol, targets of stabilizing atmospheric greenhouse gases and aerosols at 450 ppm CO_2-eq with a likely warming of around 2°C appear to be the lowest targets that are politically possible to achieve. They are not targets that are desirable to set if the objective is to avoid severe damage to the GBR and other coral reefs around the world but they are still likely to be far better than a target of 550 ppm CO_2-eq with a warming of around 3°C.

Setting targets, such as stabilizing global greenhouse gas concentrations and aerosols at no greater than 450 ppm CO_2-eq, is an essential step to normal policy setting and evaluation of effectiveness. It is a principal criticism of the policy response of the previous and new Australian governments and the Queensland Government that no targets have been set for stabilizing atmospheric greenhouse gas concentrations. The policies of the previous and the new Australian Government are inconsistent with protecting the GBR from severe impacts from climate change. Simply ignoring the impacts scientists believe will occur to the GBR is not a satisfactory or even tenable policy option.

Focus on voluntary policy measures and research

Another criticism of the policy response of the previous Australian Government was that it was virtually entirely based on voluntary policy instruments and research. There appeared to be no back-up plan if technological development failed to produce alternative energy sources and sufficient reductions in emissions. The conundrum that such policies created is that, from a policy perspective merely relying on technological change without a regulatory safety net is a huge risk. As Rump noted, forecasting the future is inherently difficult because of the significant uncertainties involved. No one knows for sure what future technological breakthroughs will occur or when.[95] Needless to say, the stakes are extremely high in this gamble. Taking a risk assessment approach, the high likelihood and severe consequences of global warming suggest that a failure to address it in a comprehensive and effective manner is a serious policy failure in terms of achieving sustainable development.

In contrast, the new Australian Government appears to be much more prepared to use direct regulation as well as market-mechanisms to regulate greenhouse gases.

---

[94] van Vuuren DP, den Elzen MGJ, Lucas PL, Eickhout B, Strengers BJ, van Ruijven B, Wonink S, and van Houdt R, "Stabilizing greenhouse gas concentrations at low levels: an assessment of reduction strategies and costs" (2007) 81 *Climate Change* 119 at 152.
[95] Rump, n 16, pp 93-104.

A surreal economic debate

A somewhat surreal economic debate is taking place about the costs of mitigating climate change in which costs such as the loss of coral reefs globally are regarded as acceptable and economically rational. This is illustrated in a recent report prepared for the Great Barrier Reef Marine Park Authority (GBRMPA) by Access Economics which calculated that the GBR contributes A$6.9 billion annually to the Australian economy or gross domestic profit (based on 2005-2006 figures).[96] This comprises A$6 billion from the tourism industry, A$544 million from recreational activity and A$251 million from commercial fishing. The report noted that the GBR generates about 66,000 jobs, mostly in the tourism industry, and brings over 1.8 million visitors to the reef each year.

Access Economics found it was unable to calculate the likely economic cost of climate change due to impacts on the GBR because of the potential for "substitution" of expenditure associated with the GBR. For example, Access Economics found a potential for substitution if less well managed reefs around the world are damaged more quickly by climate change than the GBR thereby leading to increasing tourism to the GBR and for tourist operators in the GBR to substitute other activities as corals become damaged. In effect, Access Economics found that Australia might benefit or suffer no real economic harm, at least in the short term, from climate change damaging the GBR.

In this regard a principal criticism of the highly regarded *Stern Review* is it appears to "write-off" coral reefs by recommending stabilisation targets that the authors believe will lead to loss of coral reefs. The *Stern Review* notes the impacts on coral reefs of different rises in global temperatures as follows:[97]

- **1°C warming.** … Coral reef bleaching will become much more frequent, with slow recovery, particularly in the southern Indian Ocean, Great Barrier Reef and the Caribbean. …
- **2°C warming.** … Coral reefs are expected to bleach annually in many areas, with most never recovering, affecting tens of millions of people that rely on coral reefs for their livelihood or food supply.
- **3°C warming.** …[No specific comment on coral bleaching].

While the *Stern Review* indicates "coral reef ecosystems [will be] extensively and eventually irreversibly damaged" by temperature change relative to pre-industrial levels of 0.5-2°C,[98] for what is clearly reasons of pragmatism and feasibility, the review recommends the stabilisation goal should lie within the range of 450-550 ppm CO_2-eq,[99] thereby accepting a likely warming of 2-3°C and loss of coral reefs, including the GBR.

Eric Neumayer criticised the *Stern Review* and would level a similar criticism against the Access Economics' report. He argued that many impacts of climate change

---

[96] Access Economics Pty Ltd, *Measuring the Economic & Financial Value of the Great Barrier Reef Marine Park 2005-06* (GBRMPA, Townsville, February 2007), available at http://www.gbrmpa.gov.au/corp_site/info_services/publications/research_publications/rp087/access_economics_report_0607 (viewed 7 October 2007).

[97] Stern N, *The Stern Review on the Economics of Climate Change* (Cambridge University Press, Cambridge, 2007), p 94.

[98] Stern, n 97, Figure 13.4, p 330.

[99] Stern, n 97, p 338.

involve non-substitutable loss of natural capital.[100] This argument appears a cogent one when considering the impacts such as severe damage to the GBR. The GBR should be viewed as a non-substitutable natural asset, loss of which cannot be replaced by, effectively, people putting their money into the Australian economy by doing other things as corals around the globe and in the GBR become increasingly degraded due to climate change

Economic debate that proposes it is acceptable or, at least, economically rational to "write-off" coral reefs is somewhat surreal. Policy objectives that write-off the GBR should not be acceptable for Australia or the global community. Such objectives represent dangerous climate change and, consequently, are inconsistent with the objectives of the UNFCCC and sustainable development.

Effectiveness of current policy measures

As noted earlier, evaluating the likely effectiveness of current policy measures for climate change requires them to be assessed in terms of the likelihood that they will achieve sustainable development. In terms of climate change, this means the response is likely to avoid "dangerous climate change" under the UNFCCC.

Based on the likely impacts on the GBR, targets of holding the rise of global temperatures beneath 2-3°C based on stabilizing greenhouse gas concentrations between 450-550 ppm CO_2-eq appear too high. Stabilizing greenhouse gases around 350 ppm CO_2-eq, and allowing a rise in mean global temperature of 1°C appear to be the highest targets that should be set if the GBR is to be protected from serious degradation.

Whether a target of 350, 450, or 550 ppm CO_2-eq is set, to determine the effectiveness of the legal system and overall response the question becomes whether any of these can be achieved in practice. It appears unlikely that even the 550 ppm target will be achieved under the current legal and policy framework.

Even if all parties to the Kyoto Protocol achieved their emissions targets (something that appears completely unrealistic at this point in time), the Protocol would reduce global emissions of greenhouse gases by only a small fraction of the emissions that would be likely to occur without the Protocol being in force. There are three main reasons for this. First, the Protocol sets binding targets only for developed countries thereby excluding developing countries with large emissions such as India and China. Second, it sets binding targets only for a short period (2008-2012). Third, the targets set – a net reduction of emissions from developed countries of around 5% – are themselves small. Tom Wigley modelled reductions in global temperatures assuming no further emissions reductions are achieved after 2010 than specified under the Kyoto Protocol and found the reduction in temperature by 2100 would only be 4% lower than under a "business as usual" scenario.[101] Therefore, even under a best case scenario with perfect compliance by all signatories including the United States and Australia, the Kyoto Protocol would achieve only small reductions in greenhouse emissions and expected

[100] Neumayer E, "A missed opportunity: The Stern Review on Climate Change fails to tackle the issue of non-substitutable loss of natural capital" (2007) 17 (Nos 3-4) *Global Environmental Change* 297.
[101] Wigley TML, "The Kyoto Protocol: CO_2, CH_4 and climate implications" (1998) 25(13) *Geophys. Res. Letters* 2285 at 2287. Note: Wigley assumed a climate sensitivity of 2.5°C for doubling CO_2 concentrations, which is roughly consistent with the latest IPCC projection of 3°C for doubling CO_2 concentrations.

climate change. It remains to be seen whether the current negotiations for the post-2012 commitment period will achieve significantly greater reductions.

The evidence of rising atmospheric greenhouse gases also indicates that current policies are failing to curb emissions effectively. Current growth in CO_2 emissions from the burning of fossil fuels exceeds even the "worst case" IPCC projections and no region in the world is decarbonizing its energy supply.[102]

In 2003 Rosemary Lyster reviewed the legal framework for the Australian energy sector. Her overall conclusions still appear applicable generally for Australia's regulation of greenhouse emissions. After reviewing Australia's policies and regulatory framework for greenhouse emissions she concluded:[103]

> There have been various initiatives at both the Federal and State government levels to combat the greenhouse gas emissions associated with the stationary energy sector. The question remains, however, whether or not these have been effective, and what more needs to be done before Australia has a sustainable energy policy and law framework. The overall conclusion will be that to date the efforts to control greenhouse emissions … are not sufficient. The largely voluntary measures resorted to by Australian governments have not delivered effective greenhouse emissions reductions. To be effective, mechanisms must be written into statute and be enforceable.

Lyster's conclusions in relation to the failure of voluntary measures to reduce greenhouse emissions reflects the findings of Neil Gunningham and Darren Sinclair's research into the ability of voluntary policy mechanisms to effectively control non-point source river pollution. Based on their analysis of non-point source pollution in the Swan-Canning river catchment in Western Australia they concluded:[104]

> There is little evidence to suggest that various forms of exhortation, *when used in isolation*, have the capacity to deliver tangible environmental improvements when applied to matters of non-point source pollution. Indeed, there is a substantial body of evidence … which suggests quite the contrary. Unless landholders have a self-interest in engaging in the desired environmental improvements, then information, education and voluntarism alone will usually be unable to overcome the costs barriers (and sometimes conservatism) that often inhibit change. For these reasons such measures should *not* be used as "stand alone" approaches to reducing non-point source agricultural pollution in the Swan-Canning river catchment. This is an important conclusion, yet one which policymakers have been most reluctant to hear notwithstanding a growing, and now almost overwhelming, body of evidence to support it.

Gunningham and Sinclair's conclusions appear highly relevant to greenhouse gas emissions, even though these emissions occur from both point sources and non-point sources. Their conclusions cast considerable doubt on the ability of voluntary measures alone to reduce greenhouse gas emissions to provide an effective policy response to global warming.

---

[102] Raupach et al, n 29.

[103] Lyster R, "The implications of electricity restructuring for a sustainable energy framework: what's law got to do with it?" (2003) 20 EPLJ 359 at 367.

[104] Gunningham and Sinclair D, "Non-point pollution, voluntarism and policy failure: lessons from the Swan-Canning" (2004) 21 EPLJ 93 at 103.

In 2006 Rory Sullivan evaluated the effectiveness of Australia's greenhouse policies. He noted that Australia was on target to meet its Kyoto targets, of a 108% increase over 1990 levels during 2008-2012, but commented that:[105]

> looking beyond the Kyoto Protocol to the broader goals of climate change policy, a different picture emerges. There is a general consensus that stabilising atmospheric greenhouse gas emissions at an acceptable level would require a 60-80% reduction in greenhouse gas emissions over the period 1990 to 2050 (equivalent to reductions of between 1 and 1.5% per annum over this 60 year period). From these statistics, it is clear that the [policies of the Australian Government] did not have anything like the necessary effect on reducing greenhouse gas emissions …

Sullivan's, Gunningham and Sinclair's analyses are supported by the facts of the current increases in levels of greenhouse gases in the atmosphere and the likelihood that the levels of these gases expected to cause "dangerous climate change" for the GBR are likely to be exceeded in the near future. These facts and analyses strongly suggest that the policies of the previous Australian Government, as part of a global response to climate change, were not likely to be effective in preventing climate change from causing very serious damage to the GBR.

Unfortunately, a similar conclusion appears correct for the policies of the new Australian Government also. As noted earlier, when the conclusions of the IPCC are synthesised, it becomes clear that reductions of greenhouse emissions of 60% by 2050, such as proposed by the Queensland Government and new Australian Government, are not likely to prevent serious damage to the GBR. 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 the GBR.

At present Australia has no stated goal for stabilising atmospheric greenhouse gases and global temperature rises but its emission reduction target is consistent with stabilising greenhouse gases and global temperature rises at levels that are likely to cause severe impacts to the GBR. Consequently, the current Australian policy response, as part of the global response, is failing to achieve sustainable development and is likely to lead to dangerous climate change. If the Australia Government chooses to set policy objectives that the science is saying will destroy the GBR because of pragmatism and feasibility it should be perfectly frank about publicly acknowledging this point to enable informed public debate on this important issue.

CONCLUSION

The research question addressed in this paper was whether the international and Australian response to climate change will achieve sustainable development and avoid dangerous climate change? The research tested the hypothesis that the current response to climate change will achieve sustainable development and avoid dangerous climate change. The conclusion reached is that the hypothesis is not supported by the available evidence and science. The current international and Australian environmental legal systems are not likely to be effective in preventing climate change from causing very serious damage to the GBR. Based on what we know at this point in time, particularly current greenhouse gas emissions and current policies, the impacts of climate change appear likely to cause severe impacts to the GBR.

---

[105] Sullivan R, "Greenhouse Challenge Plus: A new departure or more of the same?" (2006) 23 EPLJ 60 at 64 (footnote omitted).

From an Australian and global perspective, severe damage to the GBR represents "dangerous climate change" on all three criteria of Article 2 of the UNFCCC: not allowing ecosystems to adapt naturally; threatening food production; and unsustainable economic development. Australia recently ratified the Kyoto Protocol and has a national objective of reducing greenhouse emissions by 60% by 2050, compared with year 2000 levels. Australia has no stated goal for stabilising atmospheric greenhouse gases and global temperature rises but its emission reduction target is consistent with stabilising greenhouse gases between 450-550 ppm CO_2-eq and stabilising global temperature rises between 2-3°C above pre-industrial levels. Such levels are likely to cause severe impacts to the GBR and marine ecosystems generally. Consequently, the current Australian policy response, as part of the global response, is failing to achieve sustainable development and is likely to lead to dangerous climate change

Stabilising greenhouse gases and aerosols around 350 ppm CO_2-eq and allowing a rise in mean global temperature of 1°C appear to be the highest targets that should be set if the GBR is to be protected from serious degradation. These appear to be the highest targets that are consistent with achieving sustainable development and avoiding "dangerous climate change" in relation to the GBR. Even though these targets must be achieved by global collaboration and cannot be achieved by Australia in isolation, the Australian Government should play an active role in negotiating and implementing these targets if it considers protecting the GBR an important policy objective. At the present time the policies of the Australian Government are inconsistent with protecting the GBR from severe impacts from climate change. The likely consequences of such policies should be recognised. Simply ignoring the impacts scientists believe will occur to the GBR is not a satisfactory or even tenable policy option. Choosing not to listen to weather forecasts does not stop it raining.

Will we leave the GBR 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 CO_2-eq and stabilise the mean global temperature at 1°C or less should not be determiniative 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 such as the GBR can be used as a flagship ecosystem and a yardstick against which to measure dangerous climate change and, conversely, acceptable climate change.