The Hon Josh Frydenberg MP
Minister for the Environment and Energy
Parliament House
CANBERRA ACT 2600

Dear Minister

I attach a copy of the Independent Expert Panel's advice on coral bleaching which describes likely climate change impacts on the Great Barrier Reef.

This advice was prepared in response to Minister Hunt's request to the Panel about the bleaching event on the Great Barrier Reef and recommended action in response.

I wrote to Minister Hunt on 6 April 2016 with preliminary advice from the Panel, and followed this up on 6 May 2016 with the inclusion a background paper prepared by the Panel – *Climate change and its implications and risks for the Great Barrier Reef*. The correspondence was copied to Minister Miles.

I provide this advice to you as current Minister for the Environment and Energy and Chair of the Great Barrier Reef Ministerial Forum.

I look forward to working with you further on this important issue.

Yours sincerely

Prof Ian Chubb AC
Chair
Reef 2050 Plan Independent Expert Panel

13 December 2016

Enc

The Hon Greg Hunt MP
Minister for the Environment
Parliament House
CANBERRA ACT 2600

Dear Minister

I am writing in response to your request for advice from the Reef 2050 Independent Expert Panel on 5 April 2016 about the current bleaching event on the Great Barrier Reef and recommended action in response.

The following advice is preliminary and will be followed by more detailed advice in the coming weeks.

- The Great Barrier Reef is experiencing a serious event linked to increased water temperature, caused by climate change.

- That inexorable rise in temperature is presently supplemented by an El Nino event.

- Coral surveys are still underway and it is too early to make definitive statements about the likely extent and longevity of impacts. It is clear, however, that there is a north-south gradient with more impact and warmer waters in the northern reaches.

- It is likely that some coral will die, but the extent of that is not yet known.

- While impacts on coral through bleaching are already obvious, with some early signs of die-off in parts of the reef, the event may also be affecting other ecological communities in the Great Barrier Reef, for example seagrasses and mangroves. The latter have been less comprehensively monitored to date.

- Whilst some reefs, grasses and mangroves may recover as water temperature declines, efforts to address water quality and direct impacts must be combined with sustained global efforts in line with the Paris Accord to sharply reduce global greenhouse gas emissions to ensure long term health of the Reef.

- Governments should continue to focus efforts on improving water quality to build reef resilience. Immediate additional efforts to reduce the direct impacts from other sources will also be valuable, for example an increase in control of crown-of-thorns starfish, linked with better and strategic targeting, and research.

- Robust and essentially continuous monitoring of corals, mangroves and seagrasses will be required to ascertain the full extent of impacts, noting that some will take time to be manifest. The IEP believes that government agencies (AIMS and GBRMPA were specifically mentioned) should be additionally resourced to enable continuous monitoring on a large scale from one end of the reef to the other.

- Bleaching, coral die-off, floods, cyclones and crown-of-thorns starfish outbreaks should not be the trigger for more comprehensive monitoring, they should be events that are observed and studied as

part of a continuous monitoring program. The IEP notes that the Reef 2050 Integrated Monitoring and Reporting Programme will be key in coordinating monitoring efforts.

- Continuous monitoring will also allow study of recovery. This will be particularly valuable where there is good water quality because much can be learned from that work.

- Monitoring should be coupled with research to help better understand the impacts of increased temperature on all affected ecological communities.

- Adequate resourcing for long term monitoring should be secured, therefore, to enable measurement of the impact of the evolving environment on the health of the eco-system, as well as the impact of the anticipated more frequent or more severe weather events.

- There is a need to continue to work with people on the ground, including Traditional Owners, tourism operators and citizen scientists, to consolidate information as it becomes available and ensure that data collection methods are comparable and robust. Partners will continue to be key to the successful delivery of commitments in the Reef 2050 Plan.

I hope this interim advice is helpful. The Panel will develop further advice on bleaching to draw together available information to provide to you and Minister Miles in the coming weeks.

Yours sincerely

Professor Ian Chubb AC
Chair
Reef 2050 Plan Independent Expert Panel

Cc: The Hon Dr Steven Miles MP, Queensland Government Minister for the Environment and Heritage Protection and Minister for National Parks and the Great Barrier Reef

6 April 2016

The Hon Greg Hunt MP
Minister for the Environment
Parliament House
CANBERRA ACT 2600

Dear Minister

Following my letter of 6 April 2016, I am writing to provide more detail in response to your request for advice from the Reef 2050 Independent Expert Panel about the current bleaching event on the Great Barrier Reef and recommended action in response.

Enclosed with this letter is further advice on coral bleaching which describes likely climate change impacts on the Great Barrier Reef. It highlights the need for sustained global efforts to sharply reduce emissions of greenhouse gases.

The advice to you on 6 April 2016, which included recommendations for immediate action, remains valid. In particular, response by governments should focus on:

- Improving Water Quality

  Continued emphasis should be on addressing and improving water quality to build reef resilience. This will be critical to ensure the long-term health of the reef.

  On 5 April, the Panel endorsed three Reef Trust Phase IV projects which are targeted at water quality improvement including: *Addressing gully and stream bank erosion – reducing sediment loss in priority* regions; *Supporting Cane Farmers Trials of Enhanced Efficiency Fertilisers;* and *Reducing nitrogen loss from the Wet Tropics and Burdekin via repeated reverse auctions*. These projects will contribute to improving water quality.

  The Panel also noted the final report of the Queensland Government's Great Barrier Reef Water Science Taskforce is due to be delivered in May 2016.

- Reducing Direct Impacts

  Reducing the direct impacts from other sources where possible will be important to support recovery of the coral.

  On 5 April, the Panel endorsed a Reef Trust Phase IV project on *Improving the management of crown-of-thorns starfish.* This project will contribute to reducing direct impacts.

- Monitoring

  Adequate resourcing is required to ensure relevant science agencies (such as AIMS, GBRMPA, BoM, CSIRO and university research groups) are able to delivery long-term robust monitoring that can be used to determine the extent of impacts and recovery of reefs after injury. The Reef 2050 Integrated Monitoring and Reporting Programme will be crucial to the coordination of monitoring efforts.

  In some cases, additional research may be required to help better understand the impacts of increased temperature on affected ecological communities in the Great Barrier Reef.

Government agencies should continue to work with people on the ground, including Traditional Owners, tourism operators and citizen scientists, to consolidate information as it becomes available and to ensure that data collection methods are comparable and robust. Partners will continue to be key to the successful delivery of commitments in the Reef 2050 Plan.

I look forward to continued engagement on this and other Reef protection issues.

Yours sincerely

Professor Ian Chubb AC

Chair

Reef 2050 Plan Independent Expert Panel

6 May 2016

Encl

Cc: Hon Dr Steven Miles MP, Queensland Government Minister for the Environment and Heritage Protection and Minister for National Parks and the Great Barrier Reef

Climate change and its implications and risks for the Great Barrier Reef

Background to advice for The Hon Greg Hunt MP, Federal Minister for the Environment

6th May, 2016

The Independent Expert Panel has advised that although improving ecosystem health by managing water quality and other 'local' non-climate related threats is critical to supporting the reef, these actions must be accompanied by unremitting efforts to reduce greenhouse gas emissions because of their role in climate change.

Both long-term decadal changes in conditions on the reef (ocean warming, sea-level rise, ocean acidification) and short-term episodic events (tropical cyclones, El Niño/La Niña) affect the reef and adjacent ecosystems (terrestrial environments, mangrove swamps, sea grass beds). Mass bleaching from unprecedented thermal stress has occurred on the Great Barrier Reef in 1998, 2002 and 2016.

In 1998 and 2016, the higher temperatures attributable to climate change are amplified by an El Niño.

Our scientific focus on the Great Barrier Reef must recognize the roles of both types of events, and their interactions, in the health of the whole ecosystem. Our focus must be to seek to mitigate to the extent possible, and prepare the reef for these rapidly-evolving changes.

While coral survives in substantially different water temperatures around the world, this is a property that has evolved over a very long period. Bleaching occurs when temperatures rise by 1-2ºC above the summer maximum that is experienced at each location (Hughes et al 2003). Present-day change to the background water temperature is so rapid that there is a risk that coral has little chance to adapt to the warming waters.

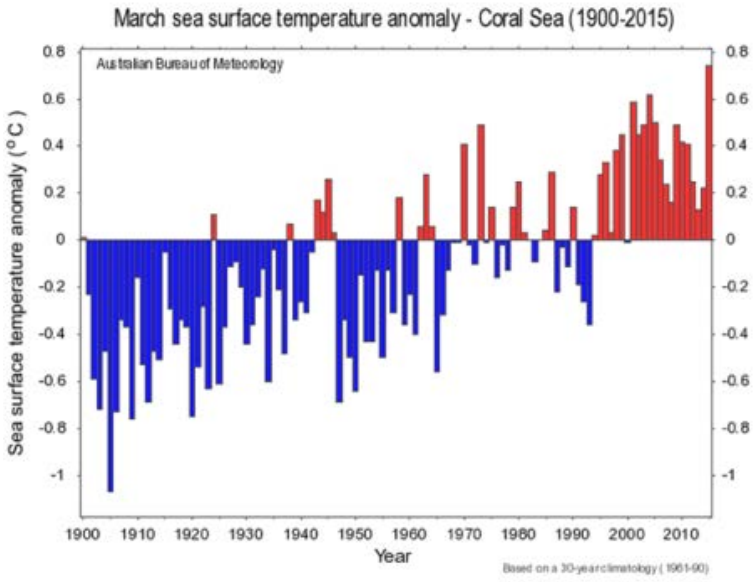
Higher water temperatures on the Great Barrier Reef are therefore driving larger and more intense mass coral bleaching and mortality events that did not occur even during El Nino periods prior to 1998. If they continue, these events are likely to cause such damage to coral-dominated communities within the Great Barrier Reef that they could be close to eliminated by mid-century.

Preserving as much of the reef as possible requires action on two fronts: in the short to medium term, improving water quality by reduced dredging and reducing land-based runoff of nutrients and pesticides from agriculture, mitigating the impact of predatory starfish outbreaks and reducing sediment runoff from erosion from all sources; in the immediate to longer term, work with, and lead, the global community in delivering the objectives of the Paris accord - that is, reducing greenhouse gas emissions globally to keep average global warming to significantly less than 2°C.

Australia's changing climate and its implications for the Great Barrier Reef and the Reef 2050 Plan: an overview.

1. Recent changes to conditions within the Great Barrier Reef region

There is extensive scientific evidence that the surface layers of the world's oceans have warmed since the beginning of the 20th century (Roemmich et al., 2015; IPCC WGI 2013). This warming has also been accompanied by well-documented and steady acidification of the ocean which is occurring at rates that dwarf any in the past 65 million years (Zeebe et al, 2016; IPCC WG1 2013;). These ongoing changes in the oceans are strongly reflected at the 'local' level of the Great Barrier Reef.



a. Sea surface temperatures within the Great Barrier Reef region have increased by almost 1°C since the beginning of last century (See Figure 1, BoM 2015). The oceans absorb more than 90% of the additional heat generated through greenhouse gases.

b. The chemistry of ocean waters has fundamentally changed at the same time as temperature has increased. More than 25% of the additional carbon dioxide in the atmosphere released by emissions is absorbed by the oceans. Ocean acidity has consequently increased by 30% over the past 150 years with a corresponding decrease in dissolved carbonate ion concentrations. This reduction in carbonate ion, reflected in global and in Australian waters (e.g. Lenton et al. 2016) both slows the rate of calcification of corals and other reef-building organisms, and increases mineral dissolution within the reef framework, compromising the Reef's ability to maintain itself over time (e.g. IPCC WGI 2013; Howard et al. 2012).

c. The world's sea levels have risen by approximately 20 cm over the last hundred years - and are currently increasing at an average rate of 3.2 mm per year. The increase is due to thermal expansion of the ocean combined with the melting of land-based ice sheets and glaciers (Watson et al. 2015; White et al. 2014). In the Great Barrier Reef region, local rates of sea level rise range up to 10 mm per year in the Torres Strait (IPCC WGI 2013).

d. The strength and timing of the episodic El Niño events may also be influenced by rising planetary temperature. If so, then these changes to the influential drought and flood cycles that have defined Australia's weather systems for millennia may be evolving, with huge ramifications for Australia. Given the vulnerability of the Great Barrier Reef to sediment and nutrient run off - any changes in rainfall patterns could have a big impact on the reef.

The long-term nature of climate change, coupled with the possible interactions of decadal-scale climate trends with episodic impacts that change year-to-year, mean we must maintain the scientific capability to continuously observe and learn about the Reef - indeed, the whole ecosystem.

2. The complex and interactive nature of climate change impacts on the Great Barrier Reef

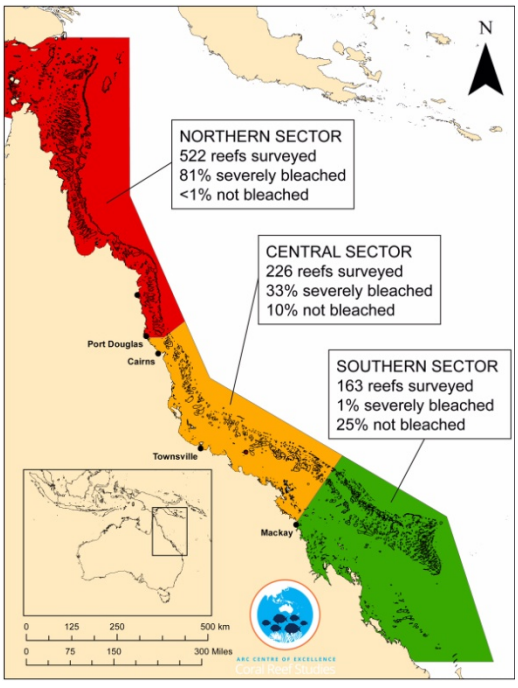
Sea-surface temperature warming events have driven mass coral bleaching and mortality events since the 1980s (e.g. Hughes et al. 2003, Hoegh-Guldberg et al. 2007). In these cases, increased sea temperature triggers the destruction of the all-important symbiosis between corals and microalgae, leading to large-scale losses of corals in many instances. The clear implication of global warming is that bleaching conditions are highly likely to become more frequent and more prolonged.

The following list includes examples of the type of other interactions that may be occurring and are the subject of active research. It is important to note that our understanding of these potential interactions is developing, thus the conclusions that can be drawn so far are preliminary. However it is essential to continue the research to understand impacts on the reef, and to plan accordingly.

a. Thermal stress, coral bleaching, recovery and the influence of local factors such as water quality

The three mass bleaching events, especially in 2016, have made a major contribution to the ongoing decline of the Great Barrier Reef. The 2016 event is by far the most severe.

Figure 2 shows the extent and severity of coral bleaching in the Great Barrier Reef World Heritage Area in March-April 2016, the most severe global warming event ever to affect the Reef (Source: ARC Centre of Excellence in Coral Reef Studies).



While the relationship between increasing sea temperatures and coral bleaching is clear (IPCC Oceans 2014), understanding how communities of corals recover from mass mortality is not well understood. For example, poor water quality can impede coral reproduction, recruitment, growth and survival, acting synergistically with the impacts of global warming and overfishing (e.g. Van de Leemput 2016). This insight reinforces the importance of implementing the Reef 2050 Plan - particularly to give the Great Barrier Reef the best chances of surviving the next decades.

b. Floods, sediments, nutrients, climate and coral reefs

There is abundant evidence that the cycling of water from evaporation to rainfall - has changed as a result of the enhanced greenhouse effect (e.g. Durack et al. 2012). These changes have increased the number of concentrated rainfall events globally, and are likely to be implicated in several recent periods of intense flooding along the Queensland coastline. In addition to affecting coastal reefs directly, these changes to the drought-flood cycle due to climate change have the potential to increase the risk of crown-of-thorns starfish outbreaks. Ensuring that we have good fundamental understanding on how the flood-drought cycle will evolve under the influence of climate change will be crucial to anticipating risks and challenges from sediments and nutrients to the Great Barrier Reef.

c. Storms, acidification and coral mechanical strength

There is considerable evidence from experiments that increasing ocean acidity will decrease the ability of many reef organisms to form their skeletons and shells. This is likely to have its greatest impact in the longer term as the effect of increasing acidity reduces any capacity to recover from the impact of sea temperature increase. The degraded structural framework of the reefs could lead to the loss of habitat for fish and other species. Storms - even without an increase in intensity - may have a bigger impact through the increasing fragility of corals as oceans acidify (Maddin et al. 2012).

d. Coastal development, mangroves, sea grass, and climate change

Coastal mangroves and sea-grass beds are a critical component of the Great Barrier Reef, providing stabilization of the sediments of coastal areas, important fishery and nursery habitats, and sequestering carbon within associated soils and muds. They are affected by rising sea tempatures, increased floods and greater storm activity.

As sea levels rise, ecosystems such as sea grass and mangroves will tend to move landward. Under current circumstances, however, the opportunity to expand into new areas along the coastline is often limited by coastal development. Understanding this interaction and specifically planning for the possible shoreward movement of these crucial ecosystems may be one response (see others in Saunders et al 2014).

3. Emerging threats and preparing for ‘unknown unknowns’

Understanding emerging threats, and preparing to detect and understand these threats and vulnerabilities as they evolve, is important given the serious and rapid changes now facing complex ecosystems like Great Barrier Reef. A few examples:

a. Complex behaviour: The Great Barrier Reef ‘House of cards’ and ecosystems shifts

Ecosystems like the Great Barrier Reef are highly complex, with many organisms responding to temperature and other stressors such as pollution in distinctly different ways. Given the importance of interactions, this complexity may lead to increasing vulnerabilities (like a ‘house of cards’) with the potential for rapid ecosystem shifts through ‘tipping points’ – transitions from which the ecosystem may not recover (e.g. Hoegh-Guldberg and Bruno 2010, Van de Leemput et a. 2016). Our understanding of these complexities and vulnerabilities is not well advanced at this point.

b. Impact of temperature on the development of the crown-of-thorns starfish (COTS)

The rate at which COTS larvae develop is highly temperature dependent. A 2°C increase in sea temperature shortens the development time of the starfish larvae, resulting in an increase in survival at the time of settlement (Uthicke et al. 2015). Consequently, population outbreaks could be enhanced by global warming.

c. Sub-bleaching impacts (growth, reproduction, calcification)

While mass coral bleaching is a prominent and visible sign of heat-stressed corals, it is the end of a series of physiological changes. Up to a point these provide protection from bleaching, but coral's thermal tolerance is likely to be overwhelmed by long-term warming (Ainsworth et al. 2016). While we have good data going back to the 1990s on the effect of thermal stress on coral bleaching, we only have a limited understanding of more subtle impacts of sub-lethal bleaching on physiological processes such as growth, reproduction and calcification. Any changes in these responses, however, could be far-reaching in their impacts, and are likely to be very important in terms of understanding how and where we might intervene to reduce the impacts of rising stress.

d. Invaders and diseases.

A consequence of rapid ocean warming is a shift in organisms' habitats to higher latitudes – we can already detect and attribute range shifts consistent with climate change (Poloczanska et al. 2013). While we are in the early days of these 'relocations', there is improving understanding of the increased risk for aquaculture (due to new diseases) and fisheries (from the impacts of alien species).

The incidence of disease has increased because stressed corals are more vulnerable and there is evidence that diseases are redistributing.

4. COP21 and current INDC commitments

The COP21 agreement between 195 nations reflected the consensus science on climate change and pledged to keep the increase in average global atmospheric temperatures well below 2°C and close to 1.5°C in the long term. While we would almost certainly continue to see declining ecosystem health on the Great Barrier Reef, these targets come with the important feature of global ocean conditions stabilizing by mid-century. Stability, in this context, is vital to enabling species and ecological processes to 'catch up' with what is otherwise a very rapidly changing set of scenarios. It is a major requirement of the survival and regeneration of the Great Barrier Reef.

The COP21 commitments, if implemented, would still see average global surface temperatures rise to 3°C or more above the preindustrial baseline (MIT 2015). Australia's vulnerabilities to climate change impacts – not the least of which is the Great Barrier Reef – mean that it is clearly in our national interest to see the COP21 commitments met, or the targets revised to meet the objective of keeping global temperature increases to below 2ºC.

5. Shorter-term, "local" management of Reef resilience in a changing world

Due to delays in changing global energy infrastructure, and inherent lag times in the climate system, challenges to the Great Barrier Reef's health are likely to intensify as the world warms over coming decades. This will lead to challenges when it comes to implementing Reef 2050 Plan within the setting of a rapidly changing world.

Further temperature increases and associated impacts on the effectiveness of the Reef 2050 Plan include:

a. Nutrient and sediment run-off from catchments and coastal activities

Increased global temperatures may increase the frequency of strong El Niño and La Niña conditions. El Niño tends to increase drought conditions and reduce the number of cyclones, while La Niña tends to favour flood events and cyclones.

Intensification of the El Niño/La Niña cycle (sometimes referred to as "ENSO") would increase the risks of nutrient loss and erosion because El Niño conditions dry soils and remove vegetation, and La Niña conditions promote floods that carry sediments and nutrients into coastal waters. ENSO-driven extremes of drought and flood contribute to a loss of water quality throughout most of the Reef.

b. Crown-of-Thorns Starfish in a changing climate

Increasing amounts of nutrients entering coastal waters, along with increased survivorship of starfish due to warmer temperatures, suggest that outbreaks of starfish may be triggered more often and may be more persistent.

c. Agrichemicals

Pesticides, herbicides and other agrichemicals are used in farming in Queensland catchments. Drought-flood cycles are likely to exacerbate the transport of these chemicals from coastal agricultural areas to the marine environment, where they can have negative impacts on marine plants and organisms.

d. Fishing

There is considerable evidence that healthy fish populations are likely to play an important role in reef recovery. Fish appear to be sensitive to both ocean warming and acidification, with changes in abundance and geographical distribution likely to continue over the coming decades. Given the importance to tourism and fisheries within the Great Barrier Reef, it will be important to detect and respond to changes driven by warming and acidifying oceans. The abundance and diversity of fishes are at risk from the likely loss of corals from the unprecedented 2016 bleaching event. i

e. Other issues

Our knowledge of the Great Barrier Reef has grown over the past 60 years, however our understanding of how the Reef is likely to change over coming decades is incomplete. The high mortality likely to follow the bleaching in 2016 is highly likely to change the species composition of corals in the northern 1000km section.

6. Summary and Conclusions

Anthropogenic climate change, if left unchecked, will prevent the achievement of the vision of Reef 2050 Plan. This would almost certainly result in further degradation of the Outstanding Universal Value of the Great Barrier Reef.

As the world is currently on a high-emissions pathway, climate change impacts are a growing challenge to the Reef, which will be more and more difficult to reverse on timescales of decades. We need to recognise there are penalties for delay, and premiums on early action to mitigate climate-induced risks.

Given the fundamental changes that are occurring across the Great Barrier Reef and adjacent ecosystems, it is crucial that we increase understanding the impacts of global change on the Great Barrier Reef.

Planning also needs to anticipate the near-certainty of more frequent mass bleaching and mortality events, more intense floods and droughts, and damage from larger storm systems. Long-term planning, close observation, and modeling, will be required to ensure Outstanding Universal Value are monitored and assessed.

Australia's natural and manmade assets – not least the Great Barrier Reef – are vulnerable to climate change impacts driven by global carbon emissions. Thus our task as a nation is to bring about a global reduction of carbon emissions.

It is vitally important that Australia show leadership and help the international community to implement the COP21 Paris Accord. If, as is predicted, the present range of agreements do not meet the objective of keeping global warming to below 2ºC on average, it is in our particular national interest for the global community to reassess targets as necessary to reach the goal.

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