LIGHTS OUT FOR THE REEF

PREPARED FOR EARTH HOUR 2014

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FOREWORD
OVE HOEGH-GULDBERG

The great barrier reef is precious to everyone. Not only is it a wellspring of marine life, it is also a favourite holiday destination, a powerful generator of jobs, and one of our most prominent national icons. Its sheer size and complexity make it an essential part of earth's biosphere.

But the Great Barrier Reef, like coral reefs everywhere, is at a turning point. If we don't increase our commitment to solve the burgeoning stress from local and global sources, the Reef will disappear. This is not a hunch or alarmist rhetoric by green activists. It is the conclusion of the world's most qualified coral reef experts.

Already Great Barrier Reef tour operators are worried about the future. After all, they know personally what losing the Great Barrier Reef would be to their businesses and livelihoods.

While the news on local threats to the reef is in itself of enormous concern, the future of the Great Barrier Reef is even bleaker when climate change and ocean acidification are considered. The scientific consensus has concluded that further increases in CO2 and average global temperature are almost certain to destroy the coral communities of the Great Barrier Reef for hundreds if not thousands of years.

And without the coral, you don't have the fish, and with the fish and coral, you don't have the billion dollar tourism industry.

It is highly unlikely that coral reefs will survive more than a 2 degree increase in average global temperature relative to pre-industrial levels. But if the current trajectory of carbon pollution levels continues unchecked, the world is on track for at least three degrees of warming. The prospect of losing our Great Barrier Reef surely demands more attention from all of us. As we fail to take action on climate change and ocean acidification, we risk pushing the Great Barrier Reef closer to the point of no return. Each tiny upward step in average global temperature brings us ever closer to that final point where it will be too late to save the Great Barrier Reef.

You and I hold the fate of our Great Barrier Reef in our hands. It is you and I, and the policies of the Governments who represent us, who will decide whether it's lights out for the Great Barrier Reef for many hundreds of years or not. If we don't act now, the climate change damage caused to our Great Barrier Reef by 2030 will be irreversible.

But if we act now, those of us alive today can be the generation that brought the Reef back from the brink.

I urge you to read this report and the Intergovernmental Panel on Climate Change released at the end of March to gain a full understanding of the science and the challenges faced by our Great Barrier Reef face if we don't decisively deal with climate change and ocean acidification.

This Saturday 29th March, I will participate in Earth Hour to make a stand for our Reef. By taking part in Earth Hour we can all build momentum towards action on climate change to help avoid a "lights out" moment for our precious and irreplaceable Great Barrier Reef.

PREFACE
ANNA ROSE

"In a world where the forests are falling and species disappearing we are blessed with places that can still be saved."

- Tim Winton, Australian author

From above, the Great Barrier Reef looks like a blue desert speckled with green jewels, stretching far into the horizon. Coral cays stud crystal clear waters dusted with fringing reefs and sandy beaches.

Under water, the reef teams with life. Reef fish dart through bright coral canyons. Coming face-to face with this underwater rainforest leaves one with a lingering sense that we're all part of something bigger.

But no matter which way you look at it, our Great Barrier Reef is one of the most vulnerable places on Earth to the impacts of climate change. The breathtaking beauty of one of our most-loved national icons is not enough to save it.

For a long time, Australians have needed the reef. Many Aboriginal and Torres Strait Islander nations lived in connection with the reef for over 60,000 years, and it continues to be a place of deep cultural and spiritual importance. In more recent times, Australian has relied on the reef to support over 63,000 livelihoods, to sustain a fishing industry, to attract tourists to our golden shores.

Even if we've never been there, the fact that our country has stewardship over a reef that can be seen from space is deeply entrenched into our national psyche. As Edward Abbey writes: "We need wilderness whether or not we ever set foot in it. We need a refuge even though we may never need to go there… we need the possibility of escape as surely as we need hope."

Now, our reef needs us. It needs us to make a stand; to fight for its survival. Our reef is under threat from many angles. This year Earth Hour will use its power to focus attention on what we must do to save it by halting the threat of climate change and ocean acidification.

Because unless our society changes course soon, we're writing the reef's death warrant in each tonne of coal and gas we mine and burn.

The impacts of climate change are already visible, in every corner of our planet. We've already changed the acidity of the oceans and the composition of the atmosphere.

But the story of how climate change is affecting our Great Barrier Reef is one of the most tangible and heartbreaking. The story of climate change can be seen and felt on the reef - in acidifying oceans, bleaching coral, increasing sand and ocean temperatures, more extreme storm damage to the reef, and rising sea levels.

Our reef is running out of time, but those of us alive today can be the ones to help save it. And just because a situation is urgent does not mean it is too late.

Earth Hour was founded on the principle that no one can do everything, but everyone can do something. Earth Hour provides a moment for you – yes, you – to have a conversation you normally might not. A conversation with friends and family about our need to tackle climate change and the carbon pollution that causes it, for the sake of our Great Barrier Reef and so much more. So this Earth Hour, on Saturday 29th March, it's time to make a stand for our Reef.

Host an Earth Hour gathering with friends and family, or attend a community gathering. Then at 8.30pm join the citizens of 152 nations and 7001 cities around the world in turning out your lights to make a stand for the reef.

Let's be proud to say we didn't sit back, but helped move a nation and a world to change course to save places like our Great Barrier Reef from climate change.

KEY FINDINGS

1.
The complexity and density of life on Australia's Great Barrier Reef makes it one of the most biodiverse places on the planet. Turtles, coral, clownfish, starfish, manta rays, sharks and dolphins are just a few of the amazing creatures that call the GBR their home. Loss of reefs and associated fauna will reduce the value of those reefs to fisheries and tourism. The Great Barrier Reef contributes around $6 billion dollars and over 63,000 jobs annually to the Australian economy through tourism and commercial and recreational fishing. These industries employ vast numbers of people and are a mainstay of regional communities along the central and north Queensland coast.

2.
The Great Barrier Reef is one of the most vulnerable places in the world to the impacts of climate change. The Great Barrier Reef is under pressure from excessive development and excessive runoff from land use, but the greatest challenge facing reefs into the future is climate change.

3.
There has been substantial damage to the reef from climate change already. The carbon pollution we put into the atmosphere today will cause further damage, if we don't act.

4.
The rapid pace of climate change and the slow pace of coral growth means that the Great Barrier Reef is unlikely to evolve quickly enough to survive the level of climate change predicted in the next few decades.

5.
Burning fossil fuels like coal and gas leads to carbon dioxide being emitted into the atmosphere and absorbed by the ocean in vast quantities. Carbon dioxide reacts with water to create a very dilute acid, which has already changed the pH of the ocean. Already, there has been a 30% increase in the hydrogen ions that cause ocean acidification. This is a major chemical change for the ocean.

6.
Ocean acidification affects the basis of the marine food chain because it decreases the concentration of carbonate ions, which is the building block of calcium carbonate. Calcium carbonate is the crucial substrate that corals and marine organisms like sea snails use to make their skeletons. Since pre-industrial times ocean carbonate levels have dropped by twenty-five per cent.

7.
An ongoing experiment conducted by The University of Queensland at Heron Island examining how future levels of climate change and associated ocean acidification will affect reefs has found it is likely that corals cannot survive more than a 2 degree global average temperature increase over pre-industrial levels before coral is no longer able to replace itself faster than coral bleaching will destroy it. If current levels of carbon pollution continue unchecked, the world is on track for at least three degrees of global average warming.

8.
Ocean acidification can also affect the ability of very young fish to avoid predators, navigate effectively and recognise parent fish, ultimately affecting their ability to survive.

9.
Climate change causes warmer ocean temperatures as well as warmer air temperatures. Ninety per cent of the extra heat generated by climate change has gone into the ocean, leading to dramatic increases in the upper 700 metres of sea water around the planet. Coral bleaching occurs when coral get too warm, and leads to coral dying in greater numbers than would otherwise have occurred. Coral bleaching is not known to have occurred before 1979 but is now a serious threat to the viability of coral reef ecosystems like the Great Barrier Reef.

10.
The action that Australia and world governments take on climate change in the next few years will determine the fate of the Great Barrier Reef. This is the critical decade to avoid climate change tipping points. Helping save the reef is of the many reasons Australia has to set stronger targets to reduce carbon pollution and make the transition from fossil fuels to renewable energy.


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INTRODUCTION

DR. SELINA WARD

Reefs are rivalled only by rainforests for their biodiversity. Globally, 500 million people rely on the biodiversity resources of tropical coral reefs. Over 275 million people live within 10 kilometres of coasts near reefs and reef fish, on which most of their livelihoods depend. Reefs contribute about one quarter of all fish catch for developing countries (Burke et al. 2011).

These numbers are set to rise as more people continue to move towards the coasts. Reefs also protect 150 000km of coastline from storms and wave action (Burke et al. 2011).

Unfortunately, reefs are one of the world's most vulnerable ecosystems, requiring clear waters that are generally low in nutrients to flourish having a very narrow temperature range within which they survive and thrive.

A recent survey by the World Resources Institute, United Nations Environment Programme and Global Coral Reef Monitoring Network concluded that more than 60% of the world's reefs are under immediate threat from over-fishing, destructive fishing and sediments and pollutants caused by land-based human activities (Burke et al. 2011).

Degradation of reefs occurs through multiple causes. Land clearing and coastal development have increased sediment and nutrient input to reefs, resulting in smothering of corals and increased competition from algae (Brodie et al. 2012b). Agricultural activities near reefs have also resulted in elevated levels of nutrients from fertiliser runoff and high levels of herbicides and pesticides which are detrimental to coral health (Tsatsaros et al. 2013).

Results of a 27-year monitoring program on the Great Barrier Reef with 2258 surveys of 214 reefs showed a decline in coral cover of 50.7% in this time. This was attributed to tropical cyclone damage (48%), the arrival and predatory activities of crown of thorns starfish (42%) and coral bleaching (10%) (De'ath et al. 2012).

Against this backdrop of the effects of human land use, destructive fishing and overfishing, the greatest challenge facing reefs globally into the future is climate change (Hoegh-Guldberg 1999).

There has been substantial reef degradation from climate change already (Hughes et al. 2003, Hoegh-Guldberg 2011), and this report will describe the ways that climate change affects reefs, the expectations for the future and what can be done to minimise the danger.

Reefs are vulnerable to at least four different effects of climate change:

- Increases in sea surface temperature
- CO_2 in the sea causing ocean acidification
- Increased intensity of storms
- Sea level rise.

TEMPERATURE

Corals have a very narrow temperature tolerance range so small increases in seawater temperature can have devastating effects.

Corals are animals that live in an ongoing partnership, known as mutualistic symbiosis, with single celled dinoflagellate algae. These dinoflagellates, known as Symbiodinium, live inside the coral cells at a density of around 1 million. cm-2 of tissue and are essential for maintaining coral health (Trench 1993). The Symbiodinium photosynthesise within the coral cells and provide up to 95% of the energy used by the coral (Muscatine et al. 1981). They also assist with the production of fats and with the calcification of the coral skeleton, which produces the three- dimensional framework of coral reefs.

In some conditions, densities of Symbiodinium are dramatically reduced and corals will "bleach" and become pale (Brown and Howard 1985, Hoegh-Guldberg and Smith 1989). This occurs when there is a reduction of 50-90% in the density of Symbiodinium.

Bleaching can be caused by a variety of stressors that interfere with the photosynthesis of the Symbiodinium (Brown and Howard 1985). This has been demonstrated experimentally using an increase or reduction in salinity (Egana and Disalvo 1982) an increase in copper ions (Jones 1997), exposure to cyanide (Jones and Hoegh-Guldberg 1999) and bacterial infection (Kushmaro et al. 1996).

However, the most important factor that causes bleaching is an elevation in seawater temperature (Coles and Jokiel 1977) and these temperatures elevations combined with clear, sunlit conditions, are responsible for mass bleaching events (Porter et al. 1989, Drollet et al. 1995, Hoegh-Guldberg 1999).

There have been many mass bleaching events since 1979 and these have coincided with periods of high sea water temperatures (Hoegh-Guldberg et al. 2007).

Satellite monitoring programs reveal that as little as a single degree above the average summer maximum for a particular reef over a few weeks can trigger a coral bleaching event, and these frequently result in mortality of corals.

A major global bleaching event in 1998, at the time the hottest year on record, resulted in the death of 16% of the world's corals (Wilkinson et al. 1999).

In 2002, the Great Barrier Reef suffered its worst bleaching (van Oppen et al. 2005), while the Caribbean reefs were devastated in 2005 and 2010 with bleaching events (Eakin et al. 2010) and the Coral Triangle, the most biodiverse reef area on the planet, suffered its worst bleaching on record in 2010 (Phongsuwan et al. 2013, Sutthacheep et al. 2013).

Not all bleached corals die but the probability of mortality increases with the length and severity of the hot period (Eakin et al. 2010).

Once a coral bleaches, it will have a much reduced energy supply and fat storage or altered lipid class composition (Grottoli et al. 2004, Rodrigues and Grottoli 2007, Rodrigues et al. 2008). Corals may grow more slowly for a period after a bleaching event (Jones and Berkelmans 2010, Howells et al. 2013). They may also have reduced reproductive output following bleaching (Baird and Marshall 2002, Ward et al. 2003) as increases in temperature can diminish fertilisation success in corals and larval characteristics can change (Heyward and Negri 2010, Negri and Hoogenboom 2011). Hence it is likely that recruitment (when the juveniles become visible on the reef, so a measure of the success of the reproductive process) will be reduced in the year following a bleaching event, which makes recovery of the reef more difficult.

Surviving heat-stressed corals are more likely to succumb to disease following a bleaching event (Harvell et al. 2007). In healthy corals, bacteria in the mucus have an antibiotic effect, protecting the colony from damaging bacteria. After a bleaching event, the bacterial community may change and this antibiotic effect can be lost, making the coral more susceptible to disease (Ritchie 2006, Ainsworth and Hoegh-Guldberg 2009).

Vibrio coralliilyticus, a globally distributed bacterium associated with multiple coral diseases, only causes coral disease at temperatures above 27°C (Kimes et al. 2012). Higher temperatures can also change bacterial communities on juvenile corals and their settlement substrates, which could inhibit new coral survival (recruitment) (Littman et al. 2010)(Webster et al. 2011).

It has been suggested that corals may be able to adapt to increasing temperatures in time to avoid the loss of reefs as the temperature continues to increase this century. Although this is an attractive idea, evidence of this occurring to date is lacking, with recent bleaching responses occurring at similar heat stress intensities to those in the 1980s.

The evolution of the thermal threshold of corals has so far not been observed at the rate required to adapt to the current rate of temperature increase, which is approximately 0.2-0.5°C per decade (Hoegh-Guldberg 2012).

One idea is that corals may change the type of Symbiodinium that they harbour in order to be better suited to the higher temperatures (Buddemeier 2004). In some studies, corals have increased the proportion one type of Symbiodinium (clade D), which can be more tolerant of high temperatures, but this change has been temporary (Berkelmans et al. 2008). Some corals with clade D have been found to grow and reproduce less than those with more thermally sensitive clades (Jones and Berkelmans 2010).

In other studies many coral species maintained the same dominant clades of Symbiodinium before and after bleaching events (Gomez-Cabrera et al. 2008, Stat et al. 2009) so this change to clade D does not appear to be an option for them. There is no evidence as yet that adult corals can take up new clades of Symbiodinium from the environment following a bleaching event.

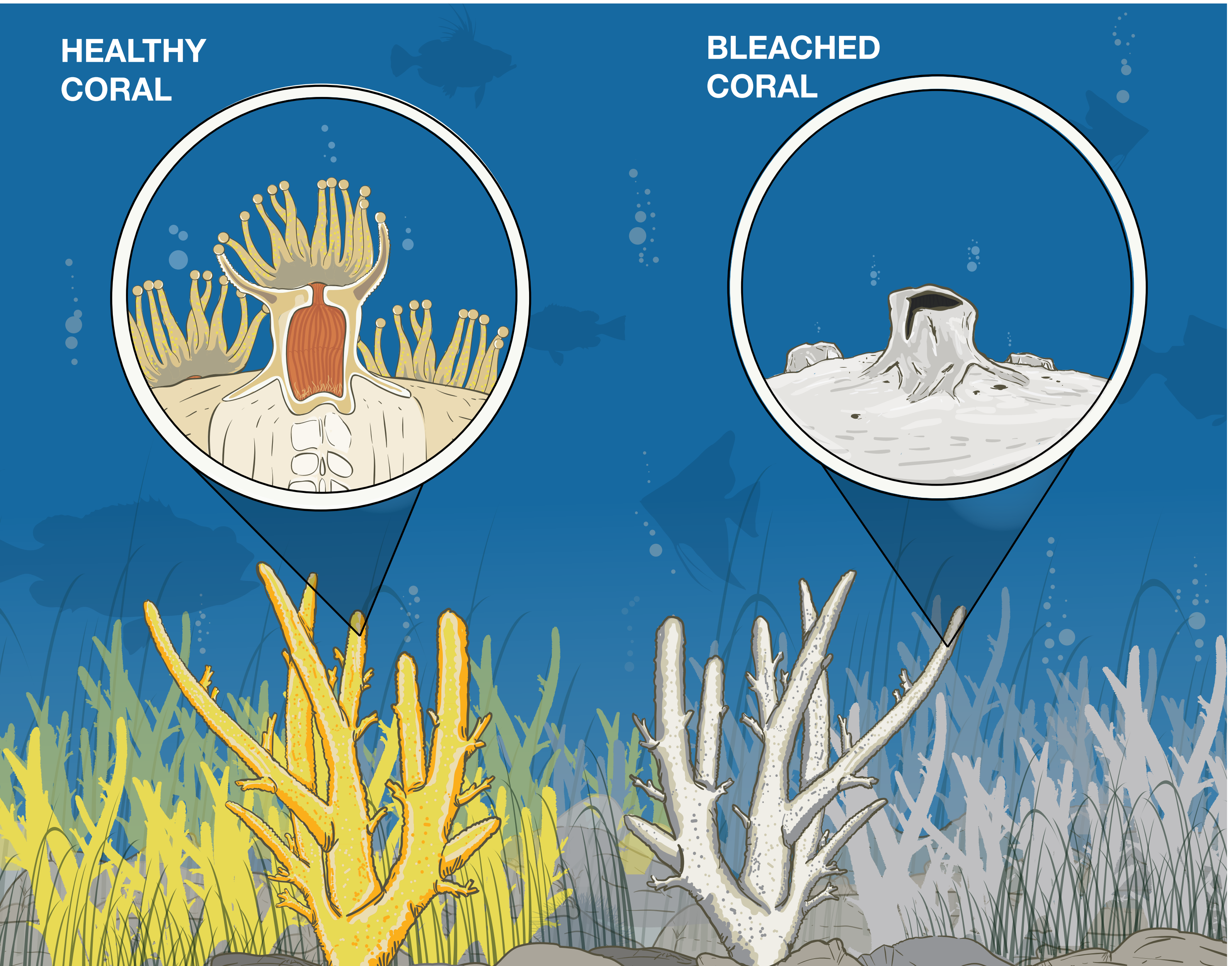
While we cannot be certain of the future for corals and coral reefs at the timescale of many millennia, it is clear that the world has already seen severe degradation of its coral reefs in extreme weather events.

At the time scale of human generations, we will lose the goods and services provided by our coral reefs if we continue to follow our current climate change trajectory (Bellwood et al. 2004, Hoegh-Guldberg 2012).

Increases in ocean temperatures don't just damage corals, they also affect fish in many ways. They are likely to affect what they eat, how they reproduce and recruit and where they live (munday et al. 2008).

The most immediate impacts will be linked to loss of healthy reef habitat which will affect diversity and fish community composition as coral cover is lost. Coral-dependent fishes suffer the most rapid population declines as coral is lost, but many other species will exhibit long-term declines due to loss of settlement habitat and erosion of habitat structural complexity (Munday et al. 2008, Pratchett et al. 2008).

Coral loss will affect the fishes that depend on live corals for food or shelter most, but many coral-reef fishes that do not depend on live coral are nonetheless dependent on the complexity of the habitat provided by healthy coral growth (Chong-Seng et al. 2012). Increased ocean temperature will affect the physiology and behaviour of coral reef fishes, particularly during the early stages of their lives. Whilst small temperature increases might assist larval development, there are likely to be negative effects on adult reproduction (Munday et al. 2008) so recruitment that is already variable will become even more unpredictable. This will make optimal harvest strategies for coral reef fisheries more difficult to determine and populations more susceptible to overfishing (Pratchett et al. 2008).



OCEAN ACIDIFICATION

KEY POINTS

- Burning fossil fuels like coal and gas leads to carbon dioxide being emitted into the atmosphere and absorbed by the ocean in vast quantities. Oceans absorb around 30% of the carbon pollution emitted by human activities, with absorption happening at the rate of about 1 tonne of C02 per person on Earth each year. These conditions are unlike any seen over the past 420 000 years.
- When carbon dioxide is absorbed by water it makes the water more acidic. Already, there has been a 30% increase in the hydrogen ions that cause ocean acidification. This is a major chemical change for the ocean and has serious implications for the Great Barrier Reef.
- Ocean acidification affects the basis of the marine food chain because it decreases the concentration of carbonate ions, the building block of calcium carbonate. Calcium carbonate is the crucial substrate that corals and marine organisms like sea snails use to make their shells and skeletons. Since pre-industrial times ocean carbonate levels have dropped by twenty-five per cent.
- Ocean acidification can also affect the ability of very young fish to avoid predators, navigate effectively and recognise parent fish, ultimately affecting their ability to survive.
- If climate change continues unchecked, scientists predict that ocean acidification will push the chemistry of the ocean outside the pH range where reefs and marine animals have survived over the past 20-40 million years.
- The change in the balance between erosion and calcification of reefs could, at current trajectories, result in a mass loss of reef structure which would continue to accelerate as the sea becomes more acidic.

The ocean behaves like a giant sponge, taking up vast quantities of anthropogenic carbon dioxide from the air.

Around 30% of the emissions of CO2 by human activities is absorbed by the ocean. This uptake is now at the rate of about 1 tonne per person on Earth per year.

As this carbon dioxide dissolves in the water, it changes the water chemistry so that the ocean becomes more acidic. In simple terms, carbon dioxide + water = carbonic acid. This change makes carbonate ions less available for the production of calcium carbonate, which is the building block for skeletons and shells of most marine invertebrates, including corals, which form the vast majority of the reef structure.

Since the industrial revolution, the pH of the ocean has dropped by 0.1 of a pH unit. As this is a logarithmic scale, this is a 30% increase in the concentration of hydrogen ions (which control acidity and carbonate availability) in the sea. These conditions are unlike any seen over the past 420,000 years. Future changes in pH depend on the rate at which carbon dioxide will be emitted in the coming decades, but most projections have the pH decreasing by 0.3-0.4 units by the end of the century (Feely et al. 2009). These changes will push the chemistry of the ocean outside those seen over the past 20-40 million years (Pelejero et al. 2010).

The fact that coral reefs and the species that depend on them will soon experience ocean chemistries outside of those under which they evolved is of great concern.

Changes in ocean pH will affect marine organisms in a number of ways; the most obvious being the predicted decrease in calcification in organisms that produce shells and skeletons of calcium carbonate, such as corals, molluscs, crustaceans, echinoderms, foraminiferans and calcifying algae (Kroeker et al. 2013). To date, experiments have shown reductions in calcification for many of these groups (Orr et al. 2005, Anthony et al. 2008, Kuffner et al. 2008, Erez et al. 2011). In short, the organisms that form the basis of the marine food chain may no longer be able to form their skeletons or shells because of a lack of calcium carbonate in the ocean.

The magnification of calcification changes due to experimental alterations in pH have not been uniform across coral species. Corals are able to increase the pH in the tiny space between the coral tissue and the skeleton where coral calcification takes place (Venn et al. 2011, McCulloch et al. 2012, Venn et al. 2013) and the scale of this change may partly determine how much each coral species is affected by ocean acidification.

To gain an insight into the conditions the Great Barrier Reef might experience under the levels of ocean acidification predicted, we can look to reefs around the world where volcanic vents have created low pH conditions. In these areas there are marked differences in biodiversity and ecological functions along a natural gradient of pH (Fabricius et al. 2011, Inoue et al. 2013). For example, when scientists observed a reef near a volcanic vent in Papua New Guinea they found reductions in coral diversity, recruitment and abundances of structurally complex framework builders, and shifts in competitive interactions between taxa (Fabricius et al 2011). Between pH levels of 8.1 and 7.8, massive Porites corals established dominance over structural corals, despite low rates of calcification. Reef development ceased altogether below pH levels of 7.7. In a similar volcanic vent location near Japan, Inoue et al (2013) found hard corals restricted to nonacidified water, soft corals present at mid level acidity and neither present at highly acidic sites. In a laboratory setting, soft corals grew well in acidified conditions even at pH as low as 7.3 (Gabay et al. 2013).

Ocean acidification can also disturb reproduction of invertebrates, include reductions in fertilisation rates (Albright and Mason 2013), settlement success and early calcification of new recruits (Albright et al. 2008, Albright and Langdon 2011) (Doropoulos et al. 2012, Doropoulos and Diaz-Pulido 2013). Since recruitment is a vital process for the survival of reefs, these results are disturbing. One study has also found that corals may bleach at lower temperatures when the pH is lower (Anthony et al. 2008).

One major problem for reefs facing ocean acidification is that reefs live in a constant balance between calcification and erosion, with the rate of erosion often more than 90% of the rate of calcification. When calcification is greater than erosion, reefs grow. However, if this balance is disturbed by a reduction in calcification by reef-builders, the reef will begin to dissolve and disappear over a long timeframe. This will have consequences for regional tourism and fisheries. In addition, it would increase the vulnerability of low lying coastal areas to storms, because of the loss of nearby fringing reefs which help to protect such areas by reducing the velocity of waves.

An experiment using patch reefs in large tanks (mesocosms) to investigate the effects of ocean acidification and temperature increases expected under 'business as usual' conditions (assuming no significant action is taken to curb climate change) compared to conditions of today, intermediate conditions, and conditions before the industrial revolution has been conducted at Heron Island recently (Dove et al. 2013). Patch reefs under the business as usual conditions decalcified, and had significant coral bleaching and coral mortality, reduction of daylight calcification and a sharp increase in nocturnal decalcification compared to today's conditions and preindustrial revolution conditions. In the "business as usual" scenario, there were negative carbon budgets and smaller carbonate sediments. The patch reefs with preindustrial treatments were significantly healthier than the ambient treatments. These observations suggest we are already past the optimal levels of pH and temperature for coral reefs to survive into the future. Fast dissolution of reef material was also observed in bioerosion rates of boring sponges at low pH treatments even though the sponges bleached with the treatment (Fang et al. 2013).

In a reef flat manipulation experiment on the Great Barrier Reef, calcium carbonate sediments went from net precipitating to net dissolving as pH was reduced (Cyronak et al. 2013). These data sets all suggest that if ocean acidification and ocean warming escalate as climate scientists predict, we could lose the Great Barrier Reef more rapidly than was previously considered.

Ocean acidification also affects very young fish. Although many life history parameters of fish are unaffected by ocean acidification in experimental work to date, studies have found that ocean acidification can cause larval fish to lose their ability to detect suitable settlement areas, to avoid predators and to recognise parent fish (Munday et al. 2009, Devine et al. 2012, Ferrari et al. 2012, Allan et al. 2013, Chivers et al. 2014). These are all vital skills for survival of larval fish. The sensory responses of fish species can be variable (Ferrari et al. 2011) with predator prey reactions varying with species and having an effect with both predator and prey exposure to increased acidification. In laboratory trials, fish exposed to ocean acidification also failed to learn the danger signs of predator fish. (Ferrari et al. 2012)

A common response to climate change to date for many terrestrial (land based) species populations is to move to cooler areas – either by moving to higher latitudes or higher altitudes. This type of migration is also possible for corals and other reef animals which have planktonic larvae, however the possibility of moving to higher latitudes is limited because the aragonite saturation, crucial for coral reefs, naturally declines with latitude (Feely et al. 2009).

The aragonite saturation is the amount of carbonate in the seawater available to organisms to build calcium carbonate. The aragonite saturation has dropped around the globe dramatically since pre-industrial times and will drop further as the carbon dioxide concentrations increase further (Silverman et al. 2009) making fewer areas suitable for reef growth. Aragonite under-saturation will therefore occur earlier in high latitude areas than in the tropics, making these less attractive for coral growth.

Coral reefs are more than just corals and fish. The inter-reefal areas are also critical in the functioning of the ecosystem and yet little is known about them. Much of their fauna is sedentary and cannot just move with increasing water temperatures. The restriction of the continental shelf south of the GBR also restricts the pole-ward movement of corals on the east coast of Australia. These changes in water temperatures, ocean currents, storm events and sea level rises are not consistent over a region as evidenced by the localised patterns of bleaching. This means some areas will be more affected than others. Such patterns make it difficult to predict exactly the levels of change. Within the Great Barrier Reef, these changes will not be uniform along the length of the reef, but all areas will be affected in some way.

SEA LEVEL RISE

According to the Australian Climate Commission, the global sea level has risen by about 20cm since the 1880s. Although estimates of the severity of future sea level rise vary (Church et al. 2013, Rohling et al. 2013, Yan et al. 2014), the Australian Climate Commission's "Critical Decade" report estimates Australia can expect sea-level rise between 0.5 and one metre compared to 2000 levels by the end of the century.

Reefs face a number of threats from sea level rise. Any time that the sea inundates the land, reefs face potential risks from water bringing pollutants and soil back to the sea. This can increase the turbidity or 'murkiness' of the water, which affects corals' ability to absorb the light they need (Brodie 1999, Brodie et al. 2012a, Erftemeijer et al. 2012). These impacts would be particularly severe around urban or agricultural coastal areas.

While increasing sea levels provide extra space for corals to grow, increases in coral bleaching events and ocean acidification will lower long-term growth rates of corals as sea level rises. At some of the higher predictions of sea level rise, some reefs would become too deep and essentially drown with insufficient light for the Symbiodinium to photosynthesise.

Increasing coastal turbidity from storm events and rising sea levels will also have an impact on seagrass beds, which are important nursery grounds for commercially important fish species feeding grounds for turtles and dugongs (Woodruff et al. 2013).

Rising sea levels will also have an impact on low lying island and beach habitats - critical nesting grounds for many seabirds and turtles.

The prospect of sea level rise around reef areas means that we need to also be concerned about industrialisation on the coastline adjacent to reefs (Erftemeijer et al. 2012). As sea level and storm intensity increase, the likelihood of industrial products and waste materials on these coastlines entering the reefal waters will increase and this will further reduce water quality and contribute to degradation of these areas.

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STORMS

Storm damage is an extremely common cause of coral mortality on the Great Barrier Reef accounting for half of the 50.7% loss of coral cover found in the 27 years of the long-term monitoring program run by the Australian Institute of Marine Science (De'ath et al. 2012).

While coral reefs in subtropical regions have always been exposed to storm and cyclone damage, they have often been able to recover in the absence of other major stressors (Dollar and Tribble 1993).

Increasing intensity of severe storms may further increase the scale of reef damage. Cyclones can dislodge corals from the reef and throw them to deeper waters or on to the shore and break off branches.

Weaker skeletons of calcifying species in response to ocean acidification (see below) are expected to be more vulnerable to breakage under more intense wave action.

Storms can also result in flooding that brings runoff and low salinity water to reefs and diminishes water quality, compounding the damaging effects from storms (Brodie et al. 2012b). Flooding can also increase nutrient levels which are associated with outbreaks of crown of thorns seastars on reefs (Brodie et al. 2005, Fabricius et al. 2010, Brodie and Waterhouse 2012).

A bleaching event causing mortality in early years of recovery would be a setback and poor water quality would be expected to make recovery more difficult.

With so many stressors present, it is likely that recovery from cyclones and severe storms will not be as quick or as direct as it might have been in past centuries.

HOW CLIMATE CHANGE IMPACTS ON REEFS WILL AFFECT HUMANS

The Great Barrier Reef contributes around $6 billion dollars annually and over 63,000 jobs to the Australian economy through tourism, and commercial and recreational fishing. Losing the reef means more than just losing a holiday spot. Loss of this iconic structure would be a terrible blow for Australia and world.

If we lose the reef structure, we lose the vast populations of other animals that rely on reefs for habitat and food supply. This includes many species of fish and a multitude of invertebrates.

Repeated bleaching events on coral reefs will lead to increased death of corals and associated invertebrates. Calcifying species will experience reduced rates of skeletal deposition. These changes will lead to increased rates of bioerosion and loss of reef substrate. As a consequence, scientists expect coral reefs to be replaced with algal dominated reefs, which are much less attractive to tourists. Algal reefs, unlike coral reefs, also have less ability to protect low-lying coastal communities from storm surges.

Sea level rise will have an impact on many nursery areas that are vital for fish and invertebrate populations; i.e., estuaries, mangrove areas and other wetlands. These will be pushed inland by rising sea levels - but in many cases, human development on land means there will be no place for these environments to migrate, and they will become reduced or disappear altogether. This will have a major negative impact on biodiversity, as well as recreational and commercial fisheries.

A broad range of policies should be put in place urgently to reduce Australia's record high per-capita carbon emissions to a much lower level.

Government policies must also protect the Great Barrier Reef from other threats, to give it the best chance of surviving the impacts of climate change that are already locked in because of past carbon pollution (see 'Reef Management Measures That Can Help Manage Climate Change Risks')

The action that Australia and world governments take on climate change in the next few years will be important in determining the fate of the Great Barrier Reef.

This is the critical decade to avoid climate change tipping points. Helping to save the reef is of the many reasons Australia must set stronger targets to reduce carbon pollution and transition from fossil fuels to renewable energy.

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REEF MANAGEMENT MEASURES THAT CAN HELP MANAGE CLIMATE CHANGE RISKS

Increasing resilience of coral reefs by minimising the stressors other than climate change should give reefs the best chance of surviving the onslaughts of climate change. Factors that should increase the resilience of reefs include ensuring that water quality on reefs is as high as possible with low nutrient, pollutant and sediment levels. To this end, the Great Barrier Reef Catchments needs to be closely managed to ensure that the levels of herbicides, pesticides and fertilisers reaching the GBR lagoon are as low as possible, and soil erosion is minimised. Riparian vegetation protection should be enforced, and riparian restoration should be continued. Incentives for improving land-use should continue. Fishing should be managed so that there is sufficient herbivory to prevent algae outcompeting corals. This may become increasingly difficult as reefs degrade and start the transition from coral dominated to algal dominated systems, as the grazing intensity of parrotfish will decline as macro algae increases. The rezoning of the Great Barrier Reef Marine Park has allowed a greater percentage of green zones and this has resulted in increases in numbers of some fish species. Industrialisation of the Great Barrier Reef coastline is not conducive to improving water quality and has many associated impacts on the Great Barrier Reef.Industrialisation of the Great Barrier Reef coastline is not conducive to improving water quality and has many associated impacts on the Great Barrier Reef. Industrialisation of the Great Barrier Reef coastline is not conducive to improving water quality and has many associated impacts on the Great Barrier Reef.To increase resilience of the reef to climate change, the practice of dredging and dumping to enable industrial development must be stopped.

Marine protected areas (including fully protected areas) are a major means by which resilience and sustainability can be enhanced. Research on the phylogeny, life history, connectivity, physiology and ecology of marine species and habitats will enable us to better understand the way populations of marine animals function, and therefore to manage them more effectively for conservation, sustainable use and climate change impact. Adequate levels of funding for research institutions is crucial for these data to become available.

When considering conserving biodiversity it is important to conserve all levels of the ecosystem if we are to have functioning ecosystems, not just the large charismatic fauna. Current resourcing for biodiversity conservation is inadequate. Species continue to be lost and increasing numbers of species and ecosystems are being recognised as threatened and formally listed as such. In addition, much of the biodiversity has yet to be described so we do not know what we are losing, hence making management difficult.

To ensure community support for local and national mitigation actions, the Australian community must have access to impartial and scientific information on climate change. Ongoing research and monitoring will need to play a key role to provide this information. Initiatives such as the Reef Guardian Councils and Schools put in place by the GBRMPA should be continued and encouraged as these inform and involve the community in issues of biodiversity conservation, which will increase the likelihood of acceptance and compliance with new zoning plans. Similar arrangements should also be initiated and receive long-term funding in other parts of Australia.

More research is required to hone our understanding of climate change impacts on the reef, and determine what measures we can take to help manage these impacts on the reef. For example, boundaries of existing marine protected areas may need to change as climate change worsens in order to preserve source and sink reefs, and increase the chances of reef species migrating to other areas. The rate of environmental change strongly affects whether and in what form coral reefs will persist, so the measures we take to address climate change today will help determine whether coral reefs will survive into the future.

CONCLUSION
ANNA ROSE - EARTH HOUR

If you've read to the end of this report, you've read the facts and figures that show how climate change is putting our Great Barrier Reef in danger. You understand that we don't have long to significantly reduce Australia and the world's levels of carbon pollution if we're going to help save the reef.

Yet if facts and figures alone could generate the political will to solve climate change, we wouldn't be in this position.

That's why need a new way to spark people's hearts, imaginations and determination to act for the sake of the reef – one that will make an entire nation sit up and take notice.

And that's where you come in.

You can make a stand for our reef and build momentum to help save it by taking part in Earth Hour, wherever you are in the world.

On Saturday 29th March, Earth Hour supporters in Australia will get together at small and large gatherings around the country.

You can have a quiet night in with family and friends, or invite your whole neighbourhood. The venue can be anything from your living room to your favourite café, pub, local community hall, place of worship, park or beach.

Together, we'll watch a world-premiere documentary special on the reef and climate change made especially for Earth Hour in Australia, before turning out the lights at 8.30pm to remind the world that if we don't stand up to protect it, it could be lights out for our Great Barrier Reef.

Learn more, and get involved, at **earthhour.org.au**

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