Submission 063
Date received: 12/08/2011

Australian Coral Reef Society

Australian Coral Reef Society Inc.

A society promoting scientific study of Australian Coral Reefs

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The Australian Coral Reef Society (ACRS) welcomes the chance to contribute to this important enquiry on the effects of climate change on biodiversity in Australia.

The Australian Coral Reef Society (ACRS) is the professional society for coral reef scientists in Australia. It is the oldest coral reef society in the world and has a considerable number of international members. It plays a key role in promoting scientific research on Australian coral reefs and is a forum for discussion and information transfer among scientists, management agencies and reef-based industries that are committed to ecological sustainability.

A large number of our members investigate the effects of climate change on a range of components of reef systems such as on corals and their symbionts, fishes, a range of invertebrate species, algae and population dynamics. Groups within our membership concentrate on gaining understanding of the impacts of temperature change, ocean acidification and storm and cyclone activity. Others study a range of other impacts such as land run off, pesticides and herbicides, oil spills, shipping accidents, invasive and pest species, overfishing and effects of tourism.

Our submission focuses on the effects of climate change on coral reefs and the biodiversity implications of these effects. We describe the four main areas of climate change that affect corals in the first section before addressing the rest of the terms of reference.

<u>Australian Coral Reef Society Council.</u>

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Inquiry into Australia's biodiversity in a changing climate

Submission from the Australian Coral Reef Society

1. Terrestrial, marine and freshwater biodiversity in Australia and its territories

Reefs and Climate Change

Reefs are rivalled only by rainforests for their biodiversity and Australia is fortunate to have some of the best managed and healthiest reefs in the world on both the east and west coasts. Globally, reefs contribute around $100 billion to the economy and around 500 million people are dependent on reefs for food, coastal protection or income, with about 30 million dependent for their livelihoods. These numbers are set to rise as more people move towards the coasts in the next decade.

Unfortunately, reefs are also one of the most vulnerable ecosystems, requiring clear waters that are generally low in nutrients to flourish and having a very narrow temperature range with which they to survive and thrive. To date, 19% of coral reefs have been lost and 35% more are seriously threatened globally, mostly due to human activities. Coral reefs in the Asia-Pacific have lost around 40% of reefs since the early 1980s. 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. 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. Ecological imbalances from increased nutrient supply are probably leading to population outbreaks of the coral eating crown of thorns seastar, which have a devastating effect on many reefs. Overfishing and increased human populations have added multiple pressures. Overfishing in many parts of the world has reduced the numbers of herbivorous fish and this can result in an increase in competition between algae and corals for space.

Against this backdrop we must consider the effects of climate change on reefs. There has been substantial reef degradation from climate change already, but we 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 climate change in four different ways – through i) increases in sea surface temperature, ii) through carbon dioxide in the sea causing ocean acidification, iii) through increased frequency intensity of storms, and iv) through sea level rise.

Temperature

Corals have a very narrow temperature tolerance range and small increases in seawater temperature can have devastating effects. Corals are animals which live in a mutualistic symbiosis with single celled dinoflagellate algae. These dinoflagellates, known as zooxanthellae, live inside the coral cells at a density of around 1 million per square centimetre of tissue and are essential for maintaining coral health. The zooxanthellae harvest sunlight through photosynthesis and provide the coral cells with up to 95% of the energy used by the coral. They also assist with the production of fats which are all important for corals, and with the calcification of the coral skeleton which produces the three-dimensional framework of coral reefs.

Under stress, the symbiosis between the coral host and its zooxanthellae is disturbed resulting in a large number of zooxanthellae leaving the coral tissues turning them pale or white. This process is known as coral bleaching. A number of different stressors can induce coral bleaching such as toxins (e.g. cyanide from destructive fishing practices), herbicides from agricultural run-off, as well as changes in salinity (terrestrial freshwater run-off), light and temperature. Recent mass bleaching events (which began around 1979) have been triggered by high sea temperatures combined with clear and sunlit conditions. 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.

Once a coral bleaches, it will have a much reduced energy supply and will struggle to make fats, grow or reproduce. In mass bleaching events, mortality is often high. In 1998, there was a global bleaching event and 16% of the corals of the world died. In 2002, the Great Barrier Reef (GBR) suffered its worst bleaching and 9% of GBR corals died. The Caribbean reefs were devastated in 2005 and 2010 with bleaching events and the Coral Triangle region suffered its worst bleaching on record in 2010.

Not all corals bleach, and not all bleached corals die; the probability of mortality increases with the length and severity of the temperature anomaly. On a smaller scale, not all reefs or even areas within a reef bleach at the same rate and factors such as water flow and water quality appear to be important in this respect. Surviving heat-stressed corals (whether or not they were fully bleached) are more likely to succumb to disease following a bleaching event. They also have reduced reproductive output for some time. Hence it is likely that recruitment will be reduced in the year following a bleaching event which makes recovery of the reef more difficult. They also grow more slowly during heat stress and for many months afterwards. Corals around the world are now growing 15-102% more slowly than 30 years ago, partly as a consequence of increasing frequencies of heat stress events.

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 increases 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. 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.

One idea is that corals may change the type of zooxanthellae that they harbour in order to be better suited to the higher temperatures. In a couple of studies, corals have increased the proportion of Clade D zooxanthellae, which is more tolerant of high temperatures, but this change of clade has been temporary and some corals many with clade D have been found to grow and reproduce less than those with other, more thermally sensitive clades. Other corals did not change their zooxanthellae after bleaching events. There is no evidence as yet that adult corals can take up new clades of zooxanthellae from the environment, but this remains an area of ongoing research.

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

The impacts of warming on other reefal invertebrates varies enormously between groups. Effects include, for example, reduced fecundity, changes in timing of spawning, reduced rates of calcification, and may result in shorter larval duration, juveniles having insufficient food supplies or being more susceptible to predation (reduced skeletal structures).

The timing of climate disturbances such as elevated water temperatures or storms is critical. If this occurs during spawning periods, it may be very damaging, but if it occurs at other stages of the life cycle it may have less impact. For most marine invertebrates there is limited data on the temperatures at which individual species die, and this is particularly true for larval life stages.

Ocean Acidification

As the ocean equilibrates with the atmosphere, it presently takes up vast quantities of anthropogenic carbon dioxide from the air. Around 30% of the emissions of CO_2 by human activities is absorbed by the ocean. This uptake is now at the rate of about 1 tonne per person per year (of the global population). 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. These changes will push the chemistry of the ocean outside those seen over the past 20-40 million years. The fact that coral reef ecosystem and their constituent species will soon experience chemistries outside those that they actually evolved under is of great concern.

Changes in ocean pH will affect marine organisms in a number of ways, the most obvious of which is 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. To date, experiments have shown reductions in calcification for many of these taxa. Marked differences in the biodiversity and ecological functions of coral reefs have been observed in areas where volcanic vents create low pH water in the sea and thus provide a window into the potential future of our reefs.

Reproduction of invertebrates can be disturbed with ocean acidification, and these disturbances include reductions in fertilisation rates, settlement success and early calcification of new recruits. Corals have been found to bleach at lower temperatures when the pH is lower. Larval fish can lose their ability to detect suitable settlement areas, to avoid predators and to recognise parent fish. These are all vital skills for survival of larval fish. Ocean acidification can also affect the pH and buffering capacity of cells and tissues, affecting important processes such as ion transport, enzyme activity and protein structure. It can also affect oxygen delivery to tissues which can change metabolic rates and energy levels.

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% 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, reef will begin to dissolve and disappear at a time scale of centuries. This will have consequences for regional tourism, fisheries and increased vulnerability of low lying areas to storms with the loss of nearby fringing reefs which help to protect such areas by reducing the velocity of waves.

Many organisms rely on coral reefs which may provide food, habitat, refuge or a place to breed, some of these animals can only live associated with live coral. Once the corals die many of these other organisms will also die or move elsewhere, resulting in local losses of biodiversity. As the coral reef becomes an algal dominated reef, a different suite of organisms will occupy the area including grazers which will eat not only the algae but reef substrate leading to loss of reef framework. Such algal dominated reefs have far less tourist appeal as all the colourful reef fish are displaced and move elsewhere.

Storms

Coral reefs in subtropical regions have been exposed to storm and cyclone damage through time, but have managed, in the absence of other major stressors, to recover from these events. Storm damage is the second-most common cause of coral mortality on the Great Barrier Reef (after outbreaks of crown-of-thorns starfish, which are triggered by drought-breaking floods). Increasing frequency of severe storms may further increase the severity of reef damage. Weaker skeletons of calcifying species in response to ocean acidification are expected to be more vulnerable to breakage under more intense wave action. Storms also result in flooding that brings runoff and low salinity water to reefs and diminish water quality, compounding the damaging effects from storms. With so many stressors present, it is likely that recovery from cyclones and severe storms may not be as quick or as direct as it might have been in past centuries. A bleaching event causing mortality in early years of recovery would be a setback and poor water quality would probably make recovery more difficult.

Sea Level Rise

The effects of sea level rise on reefs are not clearly understood but there are a number of possibilities. Any time that the sea inundates the land there is the potential to bring pollutants and soil back to the sea and this could adversely affect reefs by poisoning, adding extra nutrients and increasing turbidity. This 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 more extreme predictions of sea level rise, some reefs would become too deep and essentially drown with insufficient light for the zooxanthellae to photosynthesise.

Increasing coastal turbidity from storm events and rising sealevels will impact on seagrass beds which are important nursery grounds including many commercially important fish species as well as feeding grounds for turtles and dugongs.

Rising sea level will also impact low lying island and beach habitats which are critical nesting grounds for many seabirds and turtles.

2. Connectivity between ecosystems and across landscapes that may contribute to biodiversity conservation

Many marine species of commercial and recreational importance will undergo range alterations. Temperate marine species will suffer range reductions, and some may become extinct. As larvae develop faster at warmer temperatures, population connectivity will decrease, which will have a strong impact on the viability of populations, and upon management of living marine resources (including fisheries and marine protected areas).

A common response to climate change to date for many terrestrial populations is to move to cooler areas, either by moving to higher latitudes or higher altitudes. Such movements are also possible for corals and other reef animals which have planktonic larvae, however, the possibilities for moving to higher latitudes are limited as the aragonite saturation naturally declines with latitude. The aragonite saturation is the amount of carbonate in the seawater that is 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. Aragonite under-saturation will therefore occur earlier in high latitude areas than in the tropics.

Coral reefs are more than just corals and fish but the inter reefal areas are also critical in the functioning of the ecosystem and yet little is known about them, but 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 for example water temperatures, ocean currents, storm events and sea level rises are not consistent over a region as evidenced by the localised patterns of bleaching and some areas will be more affected than others. Such patterns make it difficult to predict exactly the levels of change and, within the GBR, these changes will not be uniform along the length of the reef, but all will be affected.

3. How climate change impacts on biodiversity may flow on to affect human communities and the economy

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, coral reefs are expected to be replaced with algal dominated reefs. This will reduce the ability of fringing reefs to protect low-lying coastal communities from storm surges. Loss of reefs and associated fauna will reduce the value of those reefs to fisheries and tourism, as algal dominated reefs have less appeal to tourists.

The Great Barrier Reef contributes around $6 billion dollars annually to the Australian economy through tourism, and commercial and recreational fishing. These industries employ vast numbers of people and are a mainstay of the communities of the Great Barrier Reef Catchment. If we lose the reef structure, we would lose the vast populations of other animals that rely on reefs for habitat and food supply. This would include the fish and a multitude of invertebrates.

Holidaying on the GBR and recreational fishing are important lifestyle activities for the Australian population and the GBR is a source of pride to the nation. Loss of this iconic structure would be a terrible psychological blow for the population.

Sea level rise will impact 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 and, 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 both recreational and commercial fisheries as well as on biodiversity in general.

4. Strategies to enhance climate change adaptation, including promoting resilience in ecosystems and human communities

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 Catchment 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. Farmers should continue to be encouraged to improve their farming practices as much as possible.

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.

5. Mechanisms to promote the sustainable use of natural resources and ecosystem services in a changing climate

Marine protected areas (including extensive no-take zones) 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 sustainable use and climate change impact. Adequate levels of funding for research institutions is crucial for these data to become available.

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6. An assessment of whether current governance arrangements are well placed to deal with the challenges of conserving biodiversity on a changing climate

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. Climate change will only increase the level of resources needed to manage and preserve and document biodiversity.

The many other coral reefs of Australia, e.g., the Coral Sea, Ningaloo and other reefs along the coast of Western Australia and the Northern Territory, as well as in the Torres Straits and Gulf of Carpentaria, urgently require a similar level of protection to that granted to the Great Barrier Reef. They require enforced and greatly expanded marine protected areas, improved management capacity and greatly increased knowledge base through intensified research.

Also more research is required to better understand impacts of climate change and amelioration methods. It is critical to record changes in the lower levels of the food chain such as the invertebrates as well as the higher level species.

Boundaries of existing marine protected areas may need to change as climate changes, in order to preserve source and sink reefs, and to provide stepping stones to enhance connectivity and population migration.

Because the rate at which the environment changes strongly affects whether and in what form coral reefs will persist, actions that slow the rate of climate change will diminish its impacts and maximize the potential for coral reefs to recover and, at geological and evolutionary time scales, adapt. Most importantly, a broad range of policies should be urgently put in place as quickly as possible to reduce Australia's record high per-capita carbon emissions to a much lower level.

7. Mechanisms to enhance community engagement

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.