The Hon Sussan Ley MP, Minister for the Environment

The Hon Meaghan Scanlon MP, Minister for the Environment and the Great Barrier Reef and Minister for Science and Youth Affairs

Dear Ministers,

I am writing on behalf of the Reef 2050 Plan Independent Expert Panel to provide our advice on changes occurring in the Great Barrier Reef (GBR) as a result of recent bleaching events. We emphasise the need to understand the Reef as an integrated ecosystem, made up of diverse components spread throughout its 350,000 square kilometres. The details are spelt out in the attachment; key points summarised below.

Coral community composition has changed in recent times due to more frequent bleaching

- Marine heatwaves induce coral bleaching – and when extended lead to coral death;
- Only 2% of >500 individual reefs that were repeatedly surveyed in 2016, 2017 and 2020 have escaped with no bleaching;
- Reefs need several years to decades to regain coral cover;
- Marine heatwaves have increased in frequency and duration in the GBR, leaving less time for reefs to recover from damage;
- Larval recruitment on the GBR by branching and tabular corals declined by an average of 93% in 2018 compared to historical levels;
- The composition of coral assemblages is therefore changing, and is less supportive of historical ecosystem complexity;
- The prospect of recovery to coral assemblages resembling those of the 1990s is poor;
- If global warming were to stabilise, remnant coral populations could reorganise into novel, more heat-tolerant reef assemblages later this century;
- Stabilising global warming requires an immediate and substantial decrease in greenhouse gas emissions.

I am happy to provide further detail on these matters if required. A second piece of advice will follow.

Yours sincerely,

Em Professor Ian Chubb AC FAA FTSE FACE FRSN

7 April 2021

Cc: The Hon Warren Entsch MP
The Hon Penny Wensley

Coral community composition has changed in recent times due to more frequent bleaching

Severe marine heatwaves trigger episodes of coral bleaching, when the relationship between corals and their single-celled algal symbionts (*Symbiodinium* spp.) breaks down, turning the coral white (Hoegh-Guldberg 1999). Bleached corals can die over a period of months if bleaching is severe and recovery of their symbionts is prolonged. Hot temperatures can also kill corals directly.

The increasing prevalence of mass mortality of corals from heat stress represents a radical shift in the dynamics of tropical reefs, causing losses of corals that far exceeds the influence of recurrent cyclones, floods and outbreaks of crown-of-thorns starfish, presenting a fundamental challenge to the long-term future of coral reefs.

The repeated die-off of corals will continue to drive a radical shift in the composition of coral assemblages (the mix of species), transforming the GBR from abundant, mature and diverse assemblages to a highly altered and degraded system.

Mass coral bleaching.

The GBR has now experienced five bouts of mass coral bleaching (i.e. bleaching that is severe and widespread) in the past 22 years - in 1998, 2002, 2016, 2017 and 2020, with less intense and more localised episodes also being reported in some other years (e.g. 1987). Each of these events was triggered by prolonged periods of exceptionally warm sea temperatures due to anthropogenic global warming. Two of these mass bleaching events, in 1998 and 2016, coincided with El Nino phases of El Nino–Southern Oscillation (ENSO) cycle - a warming of the ocean surface which drives warm and dry conditions over Australia. The other three occurred during ENSO-neutral conditions.

In 2016, half the corals that died on reef crests and upper slopes (0 to 4m) did so within 1-2 weeks of exposure to extreme temperatures (Hughes *et al*. 2018). After 8 months, close to one third of shallow-water corals (<10m depths) on the GBR had died due to heat extremes in 2016 alone (GBRMPA 2017). In the northern GBR, more than half the corals in shallow waters died between March and November 2016. There are indications of slow recovery after this major disturbance (AIMS 2020). Reefs in the southern third of the GBR that experienced less than 25% bleaching in 2016 typically had almost no loss of cover after eight months. The southern reefs were exposed to heat stress during the bleaching event in 2020 and many reefs were severely bleached (Hughes & Pratchett 2020, GBRMPA 2020). However, reefs monitored by AIMS in the Capricon Bunker and Swains sectors of the Reef experienced on average no coral loss (AIMS 2021). .

Bleaching and heat-induced mortality of corals affects some species much more than others. Scientists have categorised species into so-called winners versus losers (Loya *et al.* 2001). Winners is a relative term, because even relatively tough long-lived corals that are more tolerant of heat stress can bleach and die during extreme events (Hughes *et al*. 2018). The loss of older, slow-growing corals in 1998 and increasingly so in 2016, 2017 and 2020 is of concern, because it will take many decades to replace them. The average age and size of corals is declining, reducing the production of larvae throughout the GBR (Deitzel *et al*. 2020).

Fast-growing staghorn and tabular corals suffer the most from heat stress – they bleach easily, and survivorship is poor at high heat levels. In 2016, for example, more than half the reef crest staghorn and tabular corals died on 29% of the individual reefs comprising the GBR (Hughes et al. 2018). Those reefs, primarily in the northern GBR, shifted abruptly in 2016 away from the dominance of fast-growing, branching and tabular species that are important providers of three-dimensional habitat, to a depauperate assemblage dominated by other species with simpler morphological characteristics and slower growth rates.

The shift in the mix of coral species is important because it changes the dynamics of the broader ecosystem and is the key to understanding how climate change affects biodiversity and the functioning of ecosystems. For example, heat-sensitive corals with fast growth rates and high skeletal density strongly influence calcification. The nooks and crannies of the three-dimensional habitat provided by branching and table-shaped corals support the iconic biodiversity of coral reefs, by providing habitat for fish, crustaceans, molluscs and many other coral-dependent species. Many reef fisheries depend on ability of reef-building corals to provide habitat.

Coral reassembly is not happening the way it has in the past

The prospect is poor for a full recovery to the pre-bleaching coral assemblages of the 1990s because episodes of coral bleaching caused by anthropogenic heating will continue to become more frequent, intense, and more widespread in response to increasingly frequent high temperatures (Hoegh-Guldberg et al. 2007, Oliver et al. 2019). The most likely scenario, therefore, is that coral reefs throughout the tropics will continue to degrade over the current century.

If greenhouse gas emissions are reduced sharply, allowing climate change to stabilise, remnant populations would have the opportunity to reorganise into novel, heat-tolerant reef assemblages later this century. It is clear that the GBR will get worse before it gets better, a trajectory termed “running the climate gauntlet” (Hughes et al. 2017). The mix of coral species in the future will be unlike anything we have witnessed before. In coming decades, we predict proportionately more heat-resistant species, and other corals that are quickest to re-colonise and grow, while overall coral cover will continue to trend downwards.

The resilience of the GBR is already diminished. For example, calcification rates of colonies of very long-lived massive Porites species sharply decline for several years after coral bleaching events, leaving signatures in their skeletons of these extreme temperature stress events (Lough and Cantin 2014). Furthermore, there is already clear evidence of a reduction in recruitment of coral larvae, and a slowing of recovery rates (Osborne et al. 2017, Hughes et al. 2019). The replacement of dead corals by larval recruitment and subsequent colony growth takes at least a decade for fast-growing, highly fecund corals, such as branching species of Acropora, and Pocillopora. For slower growing species, the trajectory of replacement of dead corals on heavily damaged reefs is far more protracted - decades longer than the return-times of recent and future bleaching events.

In the aftermath of mass mortality of adult brood-stock in 2016 and 2017, larval recruitment on the GBR by branching and tabular corals declined by an average of 93% in 2018 compared to historical levels. The collapse in coral recruitment indicates that recovery of these species will be slow, and that a return to the original assemblage is highly unlikely. Observed shifts in the species composition of larvae will reinforce further widespread shifts in the composition of coral assemblages on the GBR.

The Integrity and resilience of the GBR World Heritage Area has been compromised by repeated bouts of mass beaching. Reports in the media of “recovery” refer often to the regaining of colour due (to recovery of symbionts) in surviving corals after a bleaching event, a sign of their physiological functions returning. True recovery of depleted populations (replacement of dead corals by new adults that can reproduce to sustain coral communities) is a much slower process. It is biologically impossible for a damaged reef to recover in a matter of months.

The three mass bleaching events in the past 5 years have sequentially affected the northern, central and southern regions of the GBR. Only 2% of >500 individual reefs that were repeatedly surveyed in 2016, 2017 and 2020 have escaped with no bleaching. Most offshore areas that have the potential of thermal protection due to upwelling or intrusion of deeper cooler waters (Fig. 1) (Benthuysen et al. 2016) have nonetheless bleached severely at least once since 1998. After the fifth mass bleaching event in 2020, only a small offshore southern section, a portion of the Swain group of reefs, has repeatedly escaped severe bleaching.

The ocean circulation along the outer reef is compartmentalised into zones of predominantly northwards flow in the far north, and southern flow in the central and southern regions in the sumer season (Fig 1). Although it is outside the GBR Marine Park and World Heritage Area, and not considered in the 2050 Reef Plan, the Torres Strait is biologically and geologically an integral, connected part of the GBR, particularly in the north. For central and southern parts, genetic evidence suggests that mass transport of coral larvae is mostly north to south (Riginos et al. 2019), with limited transport in the opposite direction (Fig. 1). Even if large numbers of coral larvae could disperse against the prevailing currents for many hundreds of kilometres northwards in demographically-meaningful numbers, genotypes from cooler, high latitudes in the southern GBR are likely to be maladapted to the warmer average and peak sea surface temperatures on central and northern reefs (Howells et al 2013).

The combination of current patterns, limited connectivity of coral larvae, and changes to the mix of coral species suggests that the GBR is rapidly becoming more fragmented.

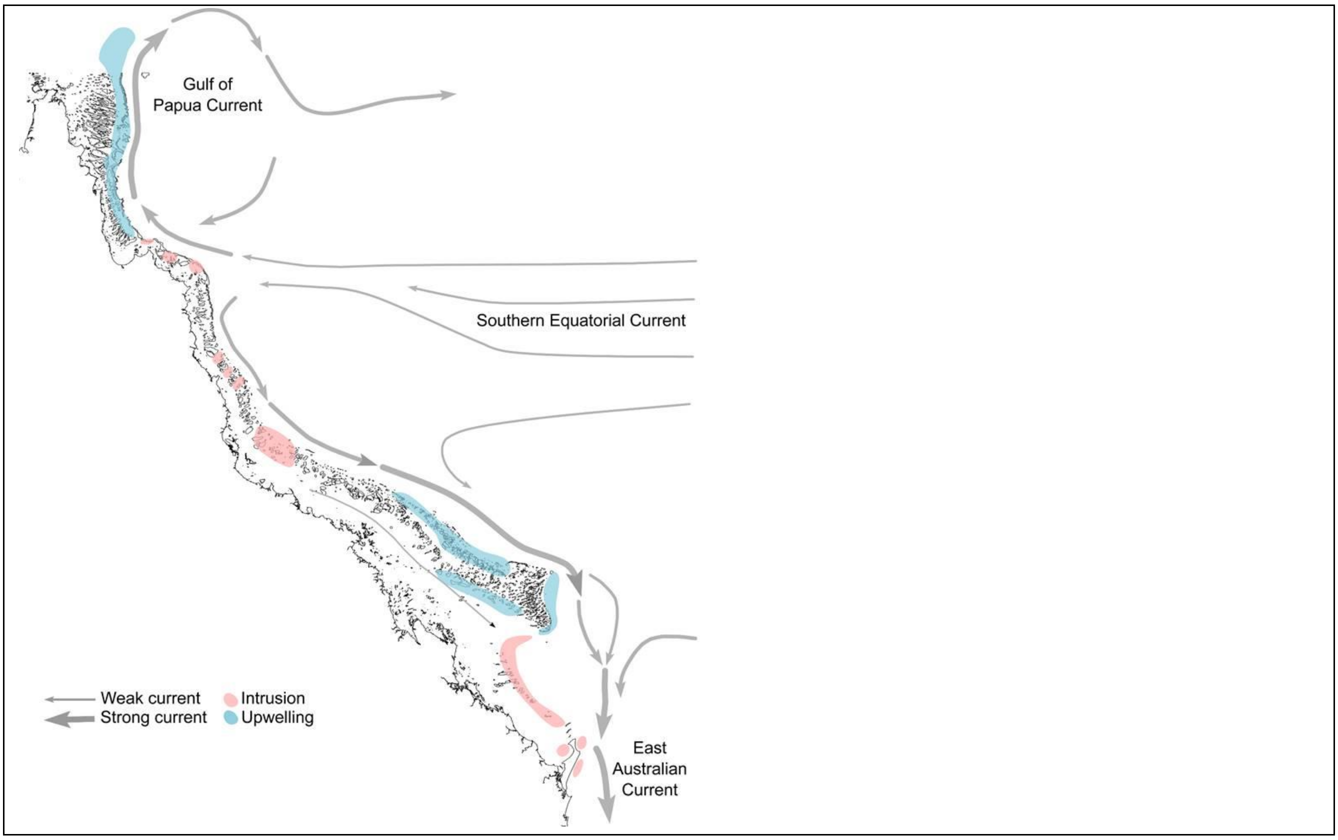

Figure 1: *Major currents and upwelling zones on the Great Barrier Reef. Virtually all areas identified as upwelling zones (blue) and area with deeper intrusion of cooler water (pink) have already bleached severely multiple times since 1998. The major currents (during the summer season) flow to the south, indicating that long-range transport of coral larvae to central and northern reefs is unlikely to be significant. Redrawn from https://eatlas.org.au/ne-aus-seascape-connectivity/circulation-upwelling*

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