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The effects of ocean acidification and warming on the early life history stages of corals

Thesis submitted by

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In January 2012

For the degree of Doctor of Philosophy in Marine Biology
within the ARC Centre of Excellence for Coral Reef Studies and the
School of Marine and Tropical Biology

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Statement on the contribution of others

Some of the chapters of this thesis are also manuscripts that have been submitted for publication in peer-reviewed journals or are in preparation for submission. Several researchers have made contributions to these manuscripts and it is necessary to recognise their contribution.

Chapter 2 is a manuscript currently in review at 'Coral Reefs' and is co-authored by W. Leggat, A. Moya and A. H. Baird. Experiments for this manuscript were performed by CMC and AM. The statistical analyses were performed by CMC and AHB. AHB, AM and WL provided constructive comments in shaping the manuscript. All authors provided intellectual input into this manuscript.

Chapter 3 is a manuscript currently in review at PLOS one and is co-authored by W. Leggat, A. Moya and A. H. Baird. AHB and WL provided ideas and helped to design the study. Experiments for this manuscript were performed by CMC and AM. The statistical analyses were performed by CMC and AHB. AHB, AM and WL provided constructive comments in shaping the manuscript. All authors provided intellectual input into this manuscript.

Chapter 4 is a manuscript nearing submission and is co-authored by W. Leggat, A. Moya and A. H. Baird. Experiments for this manuscript were performed by CMC and AM. The statistical analyses were performed by CMC and AHB. AHB, AM and WL provided constructive comments in shaping the manuscript. All authors provided intellectual input into this manuscript.

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Abstract

The rapid increase in carbon dioxide (CO₂) in the atmosphere since the industrial revolution is heating the earth and decreased the ocean's pH level. Sea temperature is predicted to rise by between 2 to 4 °C and ocean pH is predicted to decrease 0.2-0.4 units by the end of this century. These changes, along with associated changes in the carbonate chemistry of seawater, are predicted to disrupt calcification and affect the physiology of many marine organisms. While the effects of ocean acidification (OA) on adult scleractinian corals have been extensively studied, until very recently, the effects of OA on the ecology of the early life history stages of corals remained largely unexplored. Similarly, while the effects of temperature on adults and early life history stages of corals are well known, the possible synergistic effects of temperature and OA have not been examined. It is important to assess the effect of OA on the early life stages of corals in order to predict the likely effects on population dynamics. In addition, such research will provide useful guidance for managing coral reefs. To address these critical knowledge gaps, I explored the effect of OA and temperature on fertilization, development, survivorship and metamorphosis using gametes and larvae of a number of abundant scleractinian corals from the Great Barrier Reef. In the first series of experiments, I used four treatment levels of *p*CO₂ corresponding to current levels of atmospheric CO₂ (approximately 380 ppm), and three projected values within this century (550, 750 and 1000 ppm), to test whether fertilization, embryonic development, larval survivorship or metamorphosis was affected by OA. None of these variables were consistently affected by *p*CO₂ suggesting that there will be no direct ecological effects of OA on the pre-settlement stages of reef corals, at least in the near future. In a second series of experiments, I tested the effect of OA in combination with elevated temperature on the

response variables mentioned above. We used four treatments: control, elevated temperature (+2°C), decreased pH (600-700 ppm) and a combination of elevated temperature and acidity. There were no consistent effects of OA on fertilization, development, survivorship or metamorphosis either alone, or acting synergistically with temperature. In contrast, temperature consistently increased rates of development, but otherwise had little effect. I conclude that temperature is more likely to affect the ecology of the early life history stages of corals in the near future, mostly by speeding up rates of development and therefore altering patterns of connectivity among reefs. In the third set of experiments, I compared the effects of ocean acidification on the larval metamorphosis of a spawning coral *Goniastrea retiformis* and a brooding coral *Leptastrea cf transversa* in Guam. Again, metamorphosis was not consistently affected by $p\text{CO}_2$ in either species. These results suggest that the mode of reproduction does not affect the larval response to $p\text{CO}_2$ and furthermore, there will be no direct effects of ocean acidification on settlement rates of reef corals, at least in the near future. In the final set of experiments, I tested the effect of ocean acidification on its own and in combination with elevated temperature on the growth of juveniles of *Acropora millepora* and *Acropora tenuis* using the treatment levels described above. Neither OA nor temperature had any significant effect on growth or the pattern of skeleton formation in these species. I concluded ocean acidification is not a threat to the early life history stages of corals in the foreseeable future.