

PARAMETERISATION OF CORAL STRESSORS IMPACTING REEF ECO-MORPHODYNAMICS

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INTRODUCTION

Anthropogenic climate change is dramatically changing the geometry of coral reefs which has implications for shoreline protection, island formation and ecological stability (Vila-Concejo & Kench, 2017). By 2100 global mean temperature is predicted to rise a further 0.5°C (4.8°C) and sea level a further 27(67) cm based on RCP scenarios 2.6 (8.5) (IPCC, 2023). Warmer temperatures will increase the frequency of storms and cyclones, which can mechanically disturb coral communities. At the same time, ocean pH will continue to decline due to greater CO₂ absorption (IPCC, 2023), leading to losses in coral reef calcification and structural resilience. Due to the narrowing window of coral recover time resulting from a greater frequency and intensity of disturbances, there is a growing concern that coral reefs will undergo a phase shift towards algae-dominated reefs (Tebbett et al., 2022). Due to the ability to attenuate waves, corals play a crucial role in regulating the hydrodynamic energy within reefs. Consequently, phase-shifted reefs will diminish the potential for the coastal protection service that healthy reefs provide. Furthermore, reefs dominated by algae lack the sediment-forming potential seen in coral-dominated reefs, thereby influencing the stability and formation of islands.

Understanding the future trajectory of coral reefs requires in-depth research into the impacts of multiple rapid environmental disturbances. This study investigates the eco-geomorphological evolution of Lizard reef in the Great Barrier Reef (GBR) over the last 30 years under the compound effect of multiple environmental disturbances. Among these reef stressors, this study encompassed marine heatwaves, ocean acidification, bleaching events and tropical storms/cyclones. The aim of this study is to parameterise the principal cause-and-effects of climate change on coral reef eco-morphodynamics. The parameters defined by the study will be employed in an eco-morphodynamic model under-development for the GBR.

STUDY AREA

The GBR, earth's largest coral reef and living structure, has faced numerous stressors in the past decades. Occurrence of mass bleaching events within the GBR increased from every 25-30 years in the early 1980s to every 6 years in 2016 (Hughes et al., 2018). Major losses in reef structural complexity were exhibited across the entire region of the GBR following the 2016 bleaching event. The bleaching event disproportionately affected corals with accelerated growth rates and enhanced

morphological features that substantially contribute to the overall reef structural complexity (Hughes et al., 2018).

Lizard Reef (Figure 1) was recently struck by four back-to-back major disturbance events, including tropical cyclones in 2014 and 2015 and bleaching events in 2016 and 2017 (Tebbett et al., 2022). Major losses in structural complexity and hard coral cover occurred at Lizard Reef during these back-to-back disturbances (Tebbett et al., 2022). Signs of recovery at Lizard Reef between 2018 and 2022 were only observed on exposed to semi exposed sites and consisted mostly of fast-growing species (Tebbett et al., 2022). Whilst fast-growing coral dominated reefs are typically more structurally complex, they are also more vulnerable to future disturbances. This vulnerability as well as a lack of a recovery signal throughout the lagoon and back reef zone is alarming particularly as we head into an El Niño summer in 2023-24. Determining whether lizard reef is undergoing an irreversible phase-shift to an algae-dominated state remains uncertain as there is no precedent for such a frequent occurrence of disturbance events. Examining the effects and implications of recent consecutive disturbance events at Lizard Reef is crucial given the escalating frequency of major coral reef disturbances amid ongoing climate change.

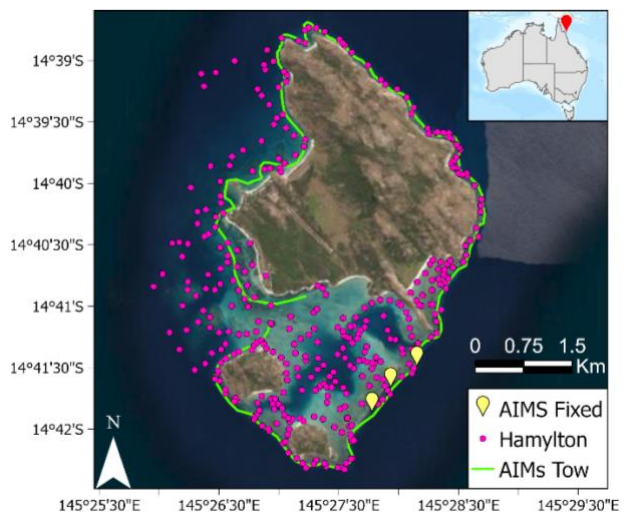


Figure 1 - Lizard Island is situated on the Northeast Australian continental shelf within the GBR (red pin). Benthic images were collected by Hamylton et al. (2014) in 2011 at 364 sites across the reef (pink dots). Video transects at 3 fixed sites along the Southeast outer slope (yellow pins) and manta-tow surveys along the reef perimeter (green line) were collected as part of the Australian Institute of Marine Science (AIMS)

Long-Term Monitoring Program. Manta-tow surveys were collected annually from 1982 to 2023 (AIMS, 2015a). Fixed sites, made up of 5x50 m transects, were surveyed annually from 1995 to 2006 and biannually from 2006 to 2022 (AIMS, 2015b).

METHODS

To investigate spatial and temporal variations in eco-geomorphology, the percentage cover of each benthic organism (based on genus and morphological classification) was calculated for each study site (figure 1). Clustering techniques were applied to group transects across space and time based on similarities within the benthic composition. To model changes in eco-geomorphology, each cluster was plotted across space and time. Environmental variables were included in the study based on the following criterium: (1) they have been affected by climate change or (2) they have a direct/indirect impact on coral reef eco-geomorphology. Examples include temperature, pH, wave energy and disturbance events such as cyclones and coral bleaching. Dimension reduction techniques and linear models were used to isolate the environmental parameters that best predict changes in the reef eco-geomorphology.

PRELIMINARY RESULTS

The cluster analysis identified three main habitat types between 1995 and 2022 along the Lizard Reef south-east margin (Figure 1). Transects belonging to habitat 1 had greater coverages of hard coral and was categorized as a healthy reef state, where reef complexity would allow for wave dissipation. Transects belonging to habitat 2 consisted almost entirely of macro and turf algae and was categorized as a struggling reef state with diminishing wave dissipating capacity. Transects belonging to habitat 3 had a mix of hard corals, soft corals and macro algae and was categorized as a coping reef state; a state that would provide minimal wave dissipation.

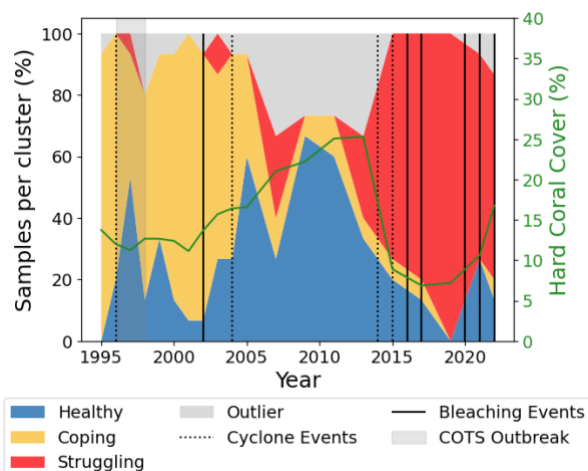


Figure 2 - Results from the AIMS fixed site surveys (Figure 1). The left y-axis represents the percent of transects colour coded based on their observed habitat type for each year (x-axis). The right y-axis represents the average hard coral cover. Major disturbance events, cyclones, bleaching and COTS outbreaks, are represented as vertical lines/boxes.

During the study period, Lizard reef fluctuated between

various states of reef health in relation to the frequency of major disturbance events (figure 2). From 1995 to 2011 Lizard Reef fluctuated between predominantly healthy and coping reef states accompanied by a period of low occurrence of disturbances. Between 2011 and 2018 there was an increase in disturbance frequency at Lizard Reef which resulted in an increase in the struggling benthic community habitats. During this period Lizard Reef was struck by Tropical Cyclone Ita (2014), Tropical Cyclone Nathan (2015), and followed by 2016 and 2017 major bleaching events. The average coral cover dropped dramatically in 2015 and remained at this level until 2021 (Figure 2). Between 2018 and 2022 some areas of the reef returned to a healthy state, but the majority are still struggling.

CONCLUDING REMARKS

The trajectory of benthic composition at Lizard reef was influenced by the frequency of major disturbance events. Based on the preliminary results of the study, consecutive major disturbance events from 2014 to 2017 significantly affected reef habitats and their ability to recover. The next phase of the experiment will look at spatial variation across the reef by adding in the other sites shown in figure 2. We will also categorise reef structural complexity/roughness over time by analysing the morphology of existing corals (e.g., branching and massive).

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