# ASSESSING CLIMATE RISKS AND VULNERABILITY OF LOW-LYING CORAL ISLANDS

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## INTRODUCTION

Coral reef islands face significant threats from climate change. They are typically less than few metres above present sea level and are composed of reef-derived sediments made from the shells and skeletons of deceased reef biota (Kench et al 2018; Dawson 2012). Coral islands and the living reefs that support them exist across a range of bio-physical conditions, and vulnerabilities to rising and warming seas, ocean acidification and increased storminess (Fellowes et al 2022; Sengupta et al 2023). In addition to the physical threats to coral island, threats that degrade or reduce the health of the living reef effect the supply of sediments to islands, may affect their structural stability by impacting sediment supply (Masselink et al 2020). Coral islands are dynamic coastal features with recent studies showing that many are growing while others are eroding (Kench et al 2018; Duvat et al 2019). It is largely unknown why some islands are resilient to change and other are not, and future stability of coral islands in the face of climate change is uncertain.

This study proposes a risk classification for coral islands based on their exposures to bio-physical ocean and climate pressures, and their eco-morphometric attributes. This research is a step towards a greater understanding of risks and vulnerabilities to coral islands. Findings have direct implications for the 65 million people worldwide that live on low-lying coral islands, including Small Island Developing States (SIDS) and provides information needed to inform policy directions and management attention.

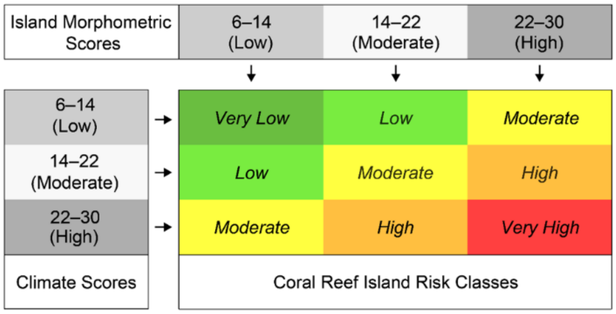
## METHODS

We considered both physical and biological controls to classify coral islands obtained from open-access imagery, climate models and remote sensing data. We first scored 6 island attributes and 6 ocean/climate proxies that are easily identified in available data (Table 1). Metrics were first scored from 1 (low) to 5 (high) risk based on breakpoints from the literature. For example, larger islands (> 100 Ha) have been shown to be more stable than smaller ones (< 10 Ha) (Kench et al 2018), thus a high risk score was assigned to smaller islands.

Table 1: Metrics used in the risk classification.

| Island Eco-morphometrics | Climate/Ocean Proxies |
|---|---|
| Size (Ha) | Tidal range (m) |
| Max elevation (m MSL) | Mean wave height (m) |
| Shape (circularity) | Total # of cyclones |
| Vegetation (% area) | Total # bleaching events |
| Beachrock (% shore) | pH (sea surface) |
| Proximity to other islands | Sea-level rise (mm/yr) |

Once the metrics were scored and totalled (out of 30) for both the island attributes and climate proxies, these two scores were combined using a risk matrix to assign islands into 1 of 5 risk classes (*Very Low* to *Very High*). (Fig 1).



| Island Morphometric Scores | 6–14 (Low) | 14–22 (Moderate) | 22–30 (High) |
|---|---|---|---|
| 6–14 (Low) | *Very Low* | *Low* | *Moderate* |
| 14–22 (Moderate) | *Low* | *Moderate* | *High* |
| 22–30 (High) | *Moderate* | *High* | *Very High* |
| Climate Scores | Coral Reef Island Risk Classes | | |

Figure 1 - Risk matrix assigns coral islands into 1 of 5 risk classes (*Very Low* to *Very High*). Modified from Fellowes et al (*in review*).

## CASE STUDY: AUSTRALIAN OFFSHORE ISLANDS

We applied the risk classification to 56 Australian coral reef islands from three offshore regions including the Coral Sea east of the Great Barrier Reef, the NW Shelf of Western Australia and the Cocos (Keeling) Islands in the Indian Ocean (Fig 2). These islands represent a broad range of eco-morphometric attributes and exposures to ocean and climate conditions.

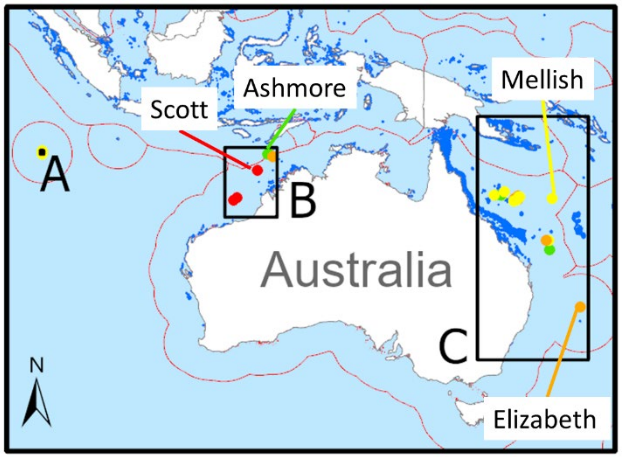


Figure 2 - Australian coral reef islands in the (a) Cocos (Keeling) Islands, (b) NW Shelf and (c) Coral Sea. Labelled reefs correspond to island images in Fig 3.

## RESULTS

No islands were assigned to the *Very Low* risk class, suggesting all islands have some degree of vulnerability. Eight islands were classed *Low* (14.3%), 34 were *Moderate* (60.7%), 11 were *High* (19.6%), and 3 were *Very High* (5.4%). Example islands from the different classes are shown in Fig 3, showing that the islands before progressively smaller, elongated and less vegetated towards *High* and *Very High* risk classes.

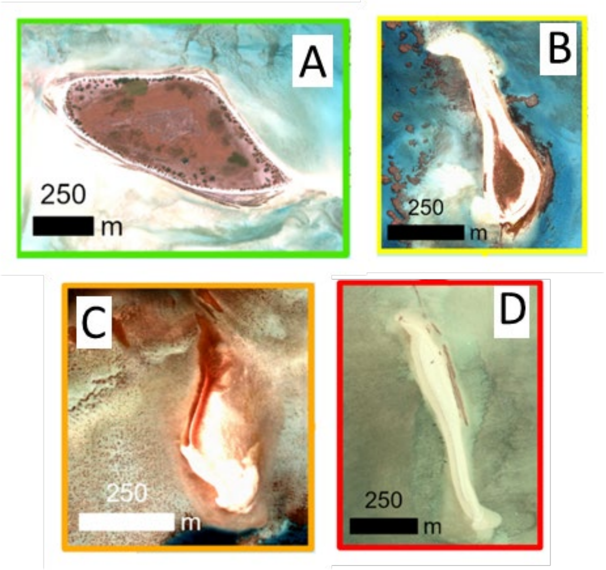


Figure 3 – Islands from different risk classes. (a) Ashmore (*Low*), (b) Mellish (*Moderate*), (c) Elizabeth (*High*), and (d) Scott (*Very High*) reef. Locations shown in Fig 2.

The 3 islands classed as *Very High* risk were all located on the NW Shelf at Scott (Fig. 3d), Clerke and Imperieuse reefs. Their high vulnerability arose from their small sizes (mean 10 Ha), low elevations (mean 2.6 m MSL), elongated shapes, unvegetated states, below average pH (mean 8.05), above average rates of sea-level rise (SLR; mean 4.6 mm/yr), isolation from other coral islands, and frequent tropical storms and marine heatwaves. Island classed as *Low* risk, for example Ashmore (Fig. 3a), got their low vulnerability from their larger size (mean 127 Ha), high elevations (mean 8.5 m MSL), round shapes, vegetated states, near average pH (mean 8.06), near average SLR rates (mean 3.9 mm/yr), proximity to adjacent islands, and infrequent cyclones and marine heatwaves.

## DISCUSSION AND IMPLICATIONS

Our approach provides a risk matrix to assess coral island vulnerability to current climate change related risks and will supports future research on the impacts of projected climate change scenarios. We have demonstrated on the Australian islands that it is possible to identify the most at-risk locations. This information will inform decision managers, including SIDS communities, with a way to focus adaptation or monitoring efforts. We are providing a baseline to investigate projected island responses and vulnerability of coral islands under different climate change scenarios. Our approach supports communities living on coral islands, associated ecosystem services and coastal States that base their legal maritime zones on these islands.

## CONCLUSIONS

This paper proposes a methodology that employs a simple and repeatable risk matrix that assesses coral islands vulnerability to climate change threats (e.g., SLR, storm, marine heatwaves) into one of five classes, ranging from *Very Low* to *Very High* risk. By using open-access and published ocean climate data, it becomes possible to include any island on a global scale. Our findings for Australian coral islands reveal that 25%, or 14 of the 56 investigated islands, are classified as *High* or *Very High* risk. We identified 3 islands with the Very High class of risk on the NW shelf of Australia. The outcomes of this study can contribute to inform coastal management and policy decisions.

## ACKNOWLEDGMENT

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