An automated GIS method for modeling relative wave exposure within complex reef-island systems: a case study of the Great Barrier Reef

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**Keywords**: wave exposure, GIS, coral reef, Great Barrier Reef

**EXTENDED ABSTRACT**

Patterns of wave energy play a significant role in shaping the long-term structure of coral reef communities worldwide. For example, sections of reefs have been shown to vary greatly in morphology (dominant size class and growth form) as coral colonies adapt in response to local-scale differences in the incoming wave heights and directions typically experienced. These differences result in zonation (crest, lagoon, and slope), producing characteristic growth forms and species assemblages that vary in their vulnerability to damage from waves. Those communities experiencing the greatest typical wave energy align themselves parallel to the water flow, adopt streamlined forms and are usually smaller in size – all of which reduces their vulnerability to wave damage. Also important to the state of reef community structure at a given time is the recent history of waves generated by high intensity, episodic events such as tropical cyclones. The greatest potential for cyclone damage occurs when waves approach a part of a reef that is typically sheltered from heavy wave action under routine conditions. In this case, corals are often more fragile and / or weakly attached to the reef, and much less wave energy is required for damage to occur than in for corals that are routinely exposed to the same forces.

Waves lose much of their energy at the leading edge of the first reef (or other shallow water obstacle) they encounter. This creates a *within-reef shelter* effect, where the lee side of the reef receives relatively little wave energy, and a *between-reef shelter* effect, where reefs beyond the first obstacle lie within a long energy 'wave shadow'. Waves passing over reefs lose energy due to changes in water depth, friction from interaction with the sea bottom, and breaking. Research suggests that waves that re-form after encountering reefs in the Great Barrier Reef (GBR) retain only about 5% of their original energy. Accordingly, research also suggests that the GBR acts as an almost complete barrier to long period waves (swell) generated seaward of the complex, even at high tide, regardless of differences in the density of reefs. Thus, the relative position of a coral community along a reef with respect to nearby reefs, islands and other shallow water obstacles plays a key role in determining its exposure to locally generated (short period) incoming waves approaching from a particular direction. The distance over which wind blows uninterrupted over water between two points limits the magnitude of the waves that form (other factors are duration and intensity). This distance, between a particular site along a reef and the nearest wave-blocking obstacle, is the fetch. Measuring the fetch at various angles around a site provides an approximation of the relative exposure of that site to waves approaching from different directions for any given wind intensity and duration. In this case, the fetch is limited to those areas of water for which the depth is sufficient for developing waves not to ‘feel the bottom’ until they break in the shallow areas that surround each site of interest.

This paper introduces a fully automated GIS model that estimates the relative exposure of sites of interest within complex reef-island systems to incoming wave energy. For each site of interest, the model estimates the fetch in all directions at a 7.5 degree interval, with a maximum fetch distance of 500 km. This information is recorded in a spatial database which can be queried to estimate relative exposure at each site from a range of incoming wave directions. For a dominant incoming wave direction, it is possible to compare the exposure of a site during routine versus high-energy conditions, such as tropical cyclones. As a case study, the model was applied to 24,224 individual sites spaced evenly (at a 1 km interval) along the ~3,000 reefs of the Great Barrier Reef (GBR). Typical exposure was compared to exposure during cyclone Joy (1990) to identify the sites most vulnerable to wave damage during that cyclone. The results were compared to field observations of actual damage at selected sites.