Modeling the Impacts of Coral Reef Restoration on Wave Energy Dissipation at Eastern Dry Rocks, Florida

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On many tropical coasts coral reefs are the primary form of coastal defense and significantly reduce wave energy that would otherwise impact shorelines. However, coral reefs' capacity to provide coastal protection is being reduced due to a range of local and global stressors and disturbances. Declines in living coral and reef structure translate to reduced reef elevation and hydrodynamic roughness, which has the potential to reduce wave dissipation. Here we report on a study of the interactions between coral restoration and wave attenuation at Eastern Dry Rocks in the Florida Keys, which is undergoing large scale restoration as part of the Mission: Iconic Reefs project. Co-located with the restoration sites, we deployed an array physical oceanographic sensors (ADCPs, pressure sensors, thermistors) at 14 sites along two across-reef transects (one on restored reef and one on a control reef) aligned across the reef flat, and down the reef slope parallel to existent reef spur and groove formations; thus spanning the wave shoaling, breaking, and dissipation zones. The array was deployed continuously from 2021-2024 and designed to provide the data required to quantify wave attenuation across the reef. The data span a wide range of conditions including six hurricanes that passed near Eastern Dry Rocks during the observational period. We are using the measurements to provide field data verification and boundary conditions for a high spatial resolution model to hindcast and predict future wave attenuation by the reef. We are using the spectral wave model SWAN with a 2.5 x 2.0 km domain centered on Eastern Dry Rocks with 5 m x 5 m computational cells. The model includes high resolution bathymetry from airborne lidar and ship-based multibeam surveys. Bottom roughness was derived from extensive Structure-from-Motion surveys. The SWAN model was validated against in situ observations under both typical and storm conditions and then used to better understand future reef properties under different restoration scenarios, including no restoration. Preliminary results suggest that, under the 2040 MIR restoration targets and conservative coral accretion scenarios, cumulative reef restoration over 25 years could enhance wave energy dissipation by approximately 10-20% through increased bottom roughness. In contrast, given that current coral substrate accretion rates at Eastern Dry Rocks are negative, the absence of restoration would likely result in a roughly 10% decrease in wave dissipation capacity. These results highlight the important role that coral restoration may play in enhancing coastal resilience over decadal timescales. Ongoing work focuses on better integrating coral growth rates into reef roughness parameterizations to improve predictive capacity under both normal baseline and extreme wave conditions.