**MODELING CORAL REEF RESTORATION TO REDUCE COASTAL HAZARDS FROM SCALES OF CENTIMETERS TO KILOMETERS**

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INTRODUCTION

Coral reefs are effective natural barriers that protect adjacent coastal communities from hazards such as erosion and storm-induced flooding. However, the degradation of coral reefs compromises their efficacy to protect against these hazards, making degraded reefs a target for restoration. At present, there is little guidance on how and where to restore coral reefs for coastal hazard risk reduction. Here we present modeling at a series of scales to provide such guidance.

CORAL SCALE (CENTIMETERS)

OpenFOAM computational fluid dynamical models on the scale of centimeters were used to explore turbulent kinetic energy dissipation over smooth and rough coral reefs for a range of wave and water level conditions (Norris et al., in review). In general, wave dissipation and near-bed turbulent kinetic energy dissipation scales with incident wave conditions, where the greatest difference between low and high relief bathymetry occurs under short-period waves.

Bottom roughness-induced turbulence kinetic energy dissipation decreases as the wave period increases. Accordingly, estimated wave energy dissipation factors ranged from 0.1 to 5, decreasing with increasing wave period. The results presented here indicate that increasing the seabed roughness by 13% through coral reef restoration could enhance wave attenuation and turbulent energy dissipation by 0.5 – 1 order of magnitude, or by 45% per across-shore meter.

REEF SCALE (METERS)

XBeach Non-hydrostatic+ hydrodynamic models on the scale of meters were used to conduct a physics-based evaluation of the optimal locations of coral restorations to reduce coastal flooding for various types of topographies (Roelvink et al., 2021). Wave-driven flooding reduction is greatest for broader, shallower coral restorations, such as on the upper fore reef and the middle of the reef flat between the reef crest and the shoreline, rather than deeper locations on the fore reef or at the reef crest. These results also indicate that to increase the coastal hazard risk reduction potential of reef restoration, more physically robust species of coral need to be outplanted in shallow regions, instead of the fragile, faster-growing species commonly grown in nurseries.

REGIONAL SCALE (KILOMETERS)

Engineering, ecologic, geospatial, social, and economic data and models were used to provide a rigorous valuation of locations where potential coral reef restoration could decrease the hazard faced by reef-fronted coastal communities. We assessed potential restoration benefits at 10 m resolution across all 980 km of Florida and Puerto’s Rico reef-lined shorelines for 3 different coral reef restoration scenarios (Storlazzi et al., 2021). We determined the coastal protection gained by coral reef restoration in Florida and Puerto Rico could result in avoided flooding affecting more than 3100 people annually; avoided direct damages of more than $124.2 million annually; and avoided indirect damages to more $148.7 million in economic activity annually. In many areas, however, reef restoration had little flood protection benefit, particularly when restoration sites were far offshore or in deep water or not in front of significant people and property.

CONCLUSIONS

These results help identify areas where coral reef restoration could potentially help reduce the risk to, and increase the resiliency of, coastal communities. The optimization and quantification of coral reef restoration efforts to reduce coastal flooding may open hazard risk reduction funding for conservation purposes.

REFERENCES

Norris, Storlazzi, Pomeroy, Rosenberger, Logan, Cheriton (in review): Combining field observations and fine-scale numerical modeling to demonstrate the effect of coral reef roughness on turbulence and its implications for reef restoration design. *Coastal Engineering*

Roelvink, Storlazzi, van Dongeren, Pearson (2021): Coral reef restorations can be optimized to reduce coastal flooding hazards. Frontiers in Marine Science, 8:653945, doi: 10.3389/fmars.2021.653945

Storlazzi, Reguero, Cumming, Cole, Shope, Gaido, Viehman, Nickel, Beck, (2021): Rigorously valuing the coastal hazard risks reduction provided by potential coral reef restoration in Florida and Puerto Rico. *U.S. Geological Survey Open-File Report 2021–1054*, 35 p., [doi: 10.3133/ofr20211054](https://doi.org/10.3133/ofr20211054)