Optimization of coral reef restoration projects to optimize wave energy dissipation Part I: Methods

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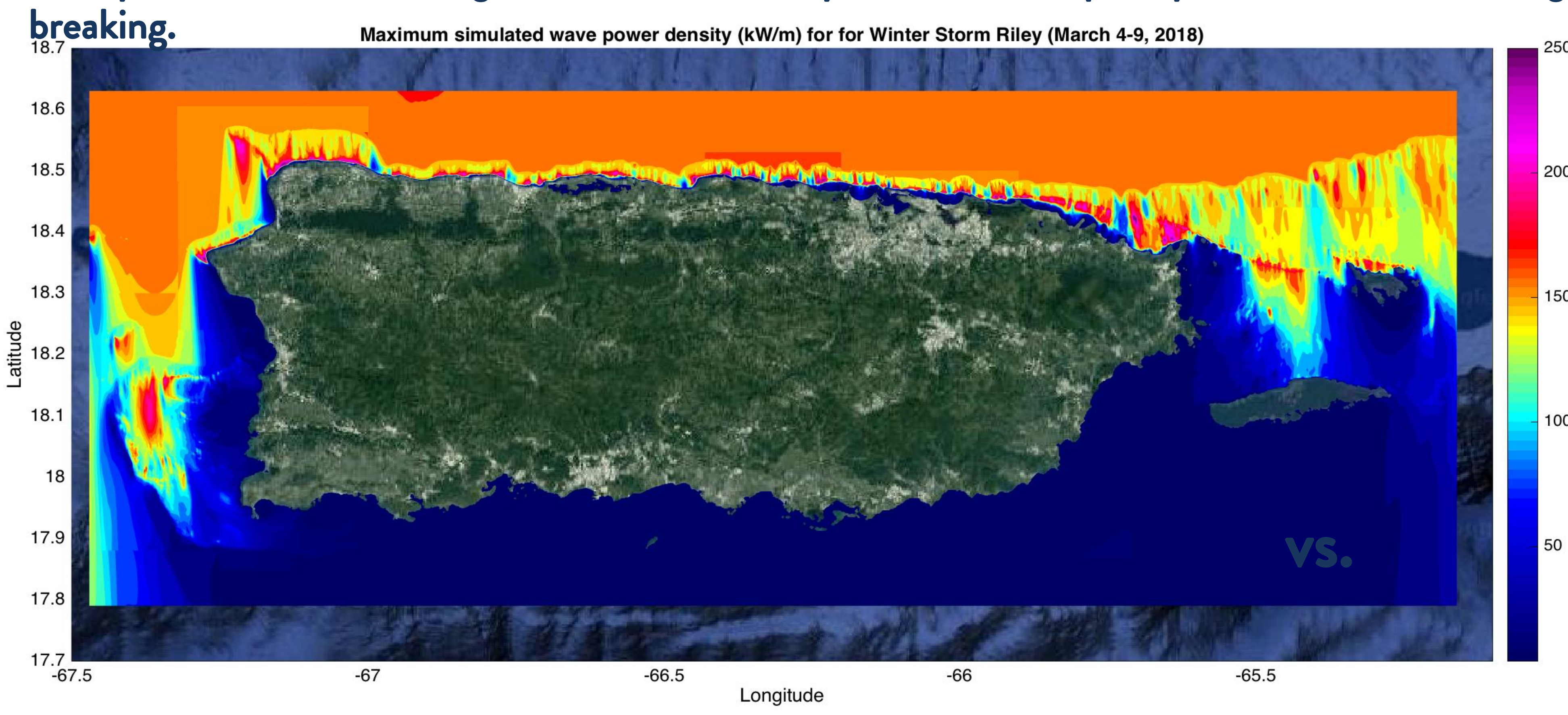
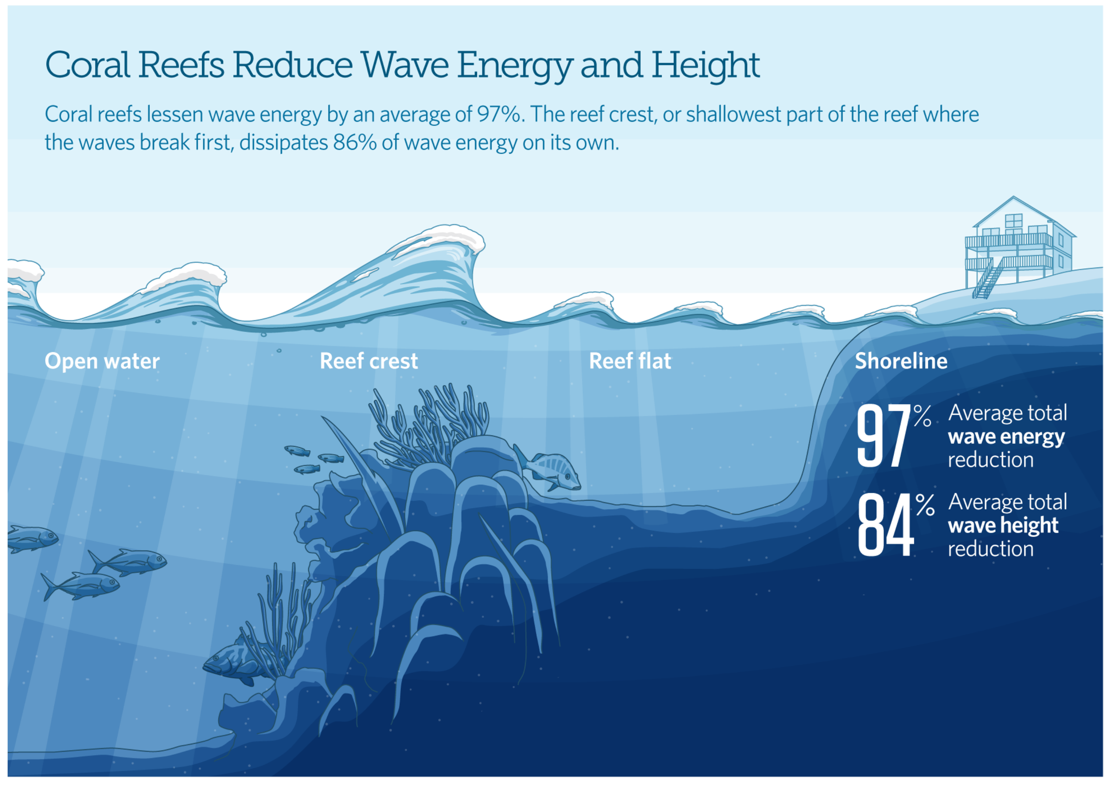
THE PROBLEM

Two main mechanisms leading to the dissipation of wave energy by coral reefs that can be controlled or enhanced via coral reef restoration efforts:

- Depth-induced wave breaking
- Wave dissipation due to bottom drag & friction

At short time scales (<10 years), wave dissipation by restored reefs (without seabed modification) is mostly due to enhanced drag ("friction") caused by structural complexity, rather than enhancing wave breaking.



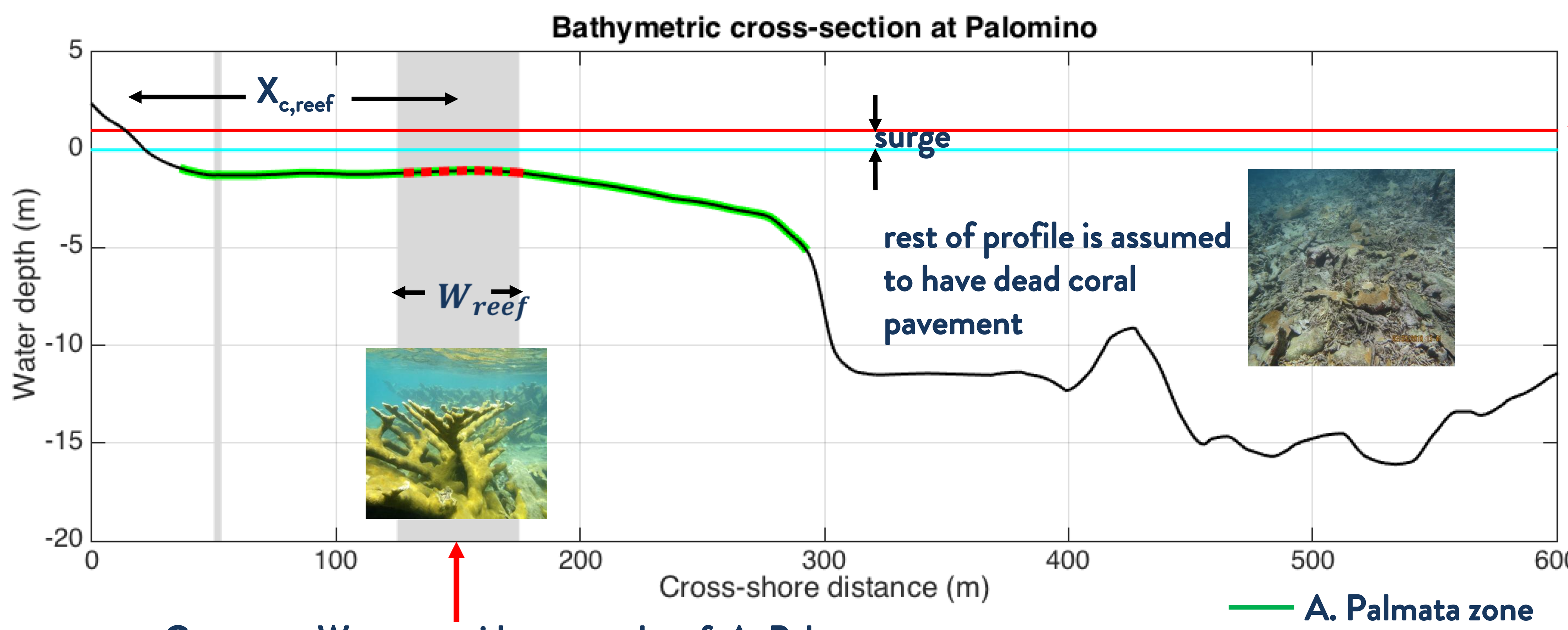


Source: F. Ferrario, M.W. Beck, C.D. Storlazzi, F. Micheli, C.C. Shepard, and L. Airoldi, "The Effectiveness of Coral Reefs for Coastal Hazard Risk Reduction and Adaptation," *Nature Communications* (2014), doi: 10.1038/ncomms4794

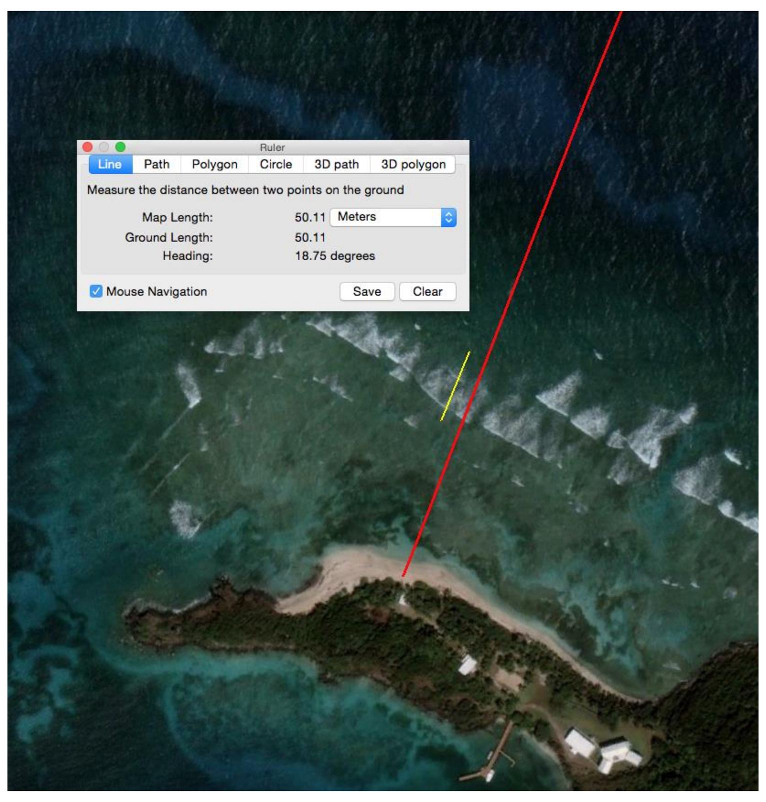
Wave breaking dissipation = f(wave steepness, wave height / depth ratio, seabed slope)

Wave dissipation through drag / friction = f(coral roughness, ratio of orbital excursion to roughness, percent coral cover…)

PALOMINO TESTBED



Gray area: W-meter wide restored reef, A. Palmata



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Quantities we want to maximize:

- Decrease in wave power at shoreline
- Decreased inland extent of flooding

$$f(H, T, W_{reef}, X_{c,reef}, R_{bg}, R_{rr}, surge, slopes…)$$

Design criteria and limitations

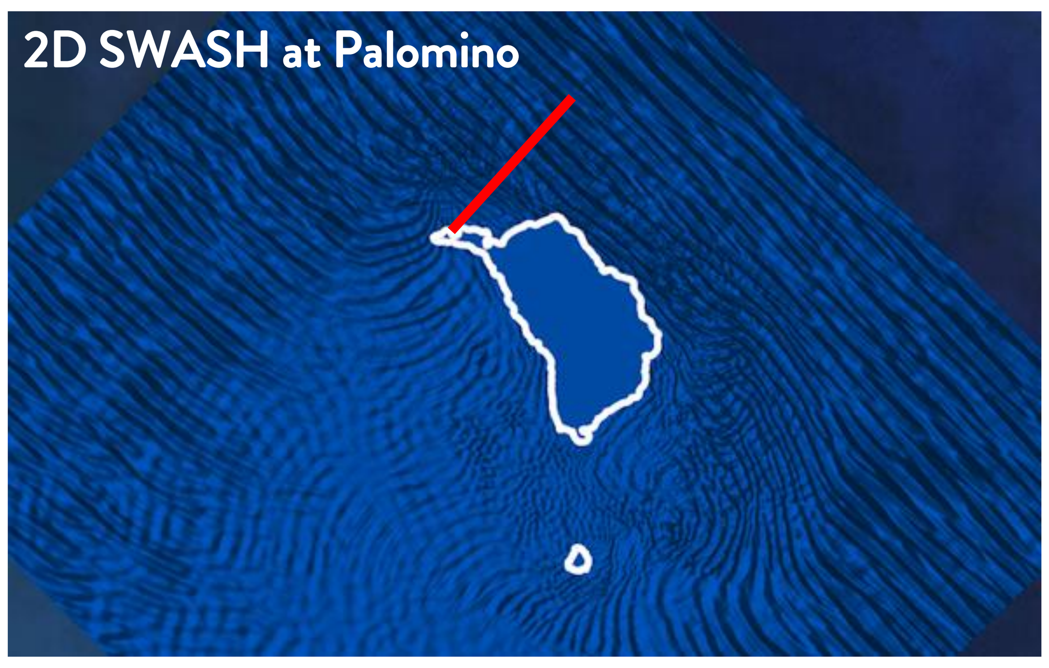
- *A. Palmata* thickets
- Depths of 1-5 meters
- Limited $ resources: cross-shore extent O(10m)

For which conditions do we optimize?

- Storm conditions – to reduce damage during a specific storm
- Cumulative impacts – will decrease wave energy and can promote shoreline accretion during "day to day" conditions

NUMERICAL WAVE MODEL SETUP

- SWASH is a nonhydrostatic phase resolving model that can be run in 1D, 2D or 3D mode (Zijlema, Stelling, & Smit, 2011).
- Settings:
  - 2DV mode, 20 layers (accurate wave breaking)
  - Drag: array of vertical cylinders with comparable frontal area and colony density to A. Palmata thickets
  - Drag force only (avoid overestimating dissipation)
  - Spectral BC's, water levels and wind stress from CARICOOS regional models (FVCOM, SWAN, WRF)



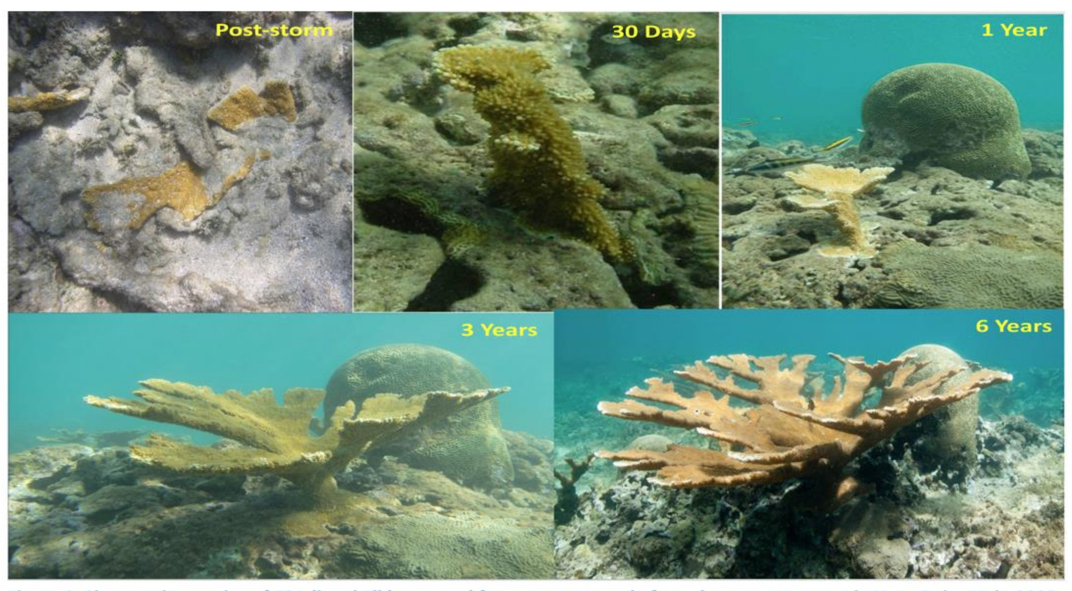
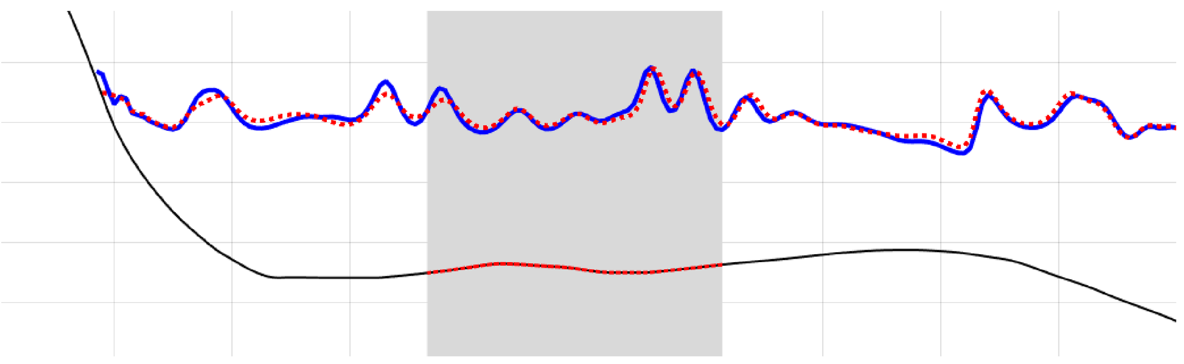


Figure 3. Six year time series of ESA-listed Elkhorn coral fragments rescued after a large storm event in Vega Baja, PR in 2008.



OPEN QUESTION: How does the reef's capabilities to dissipate wave energy through enhanced drag vary over time?

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