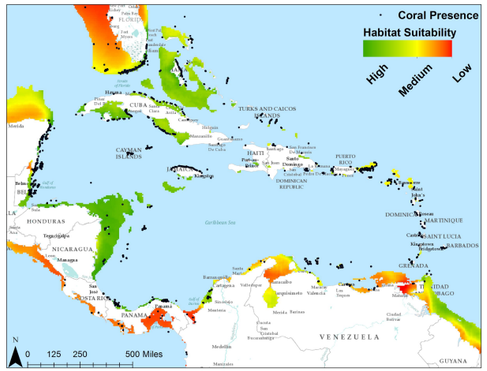
Suitability Analysis

RESULTS

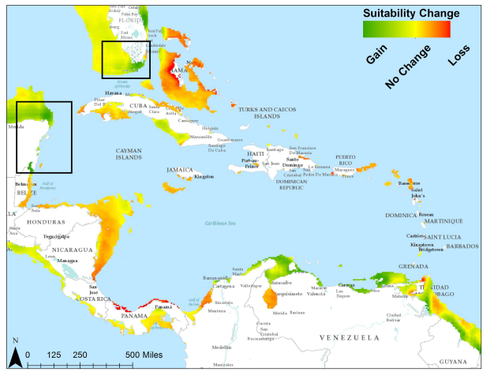
Present Coral Suitability (2005 - 2015)



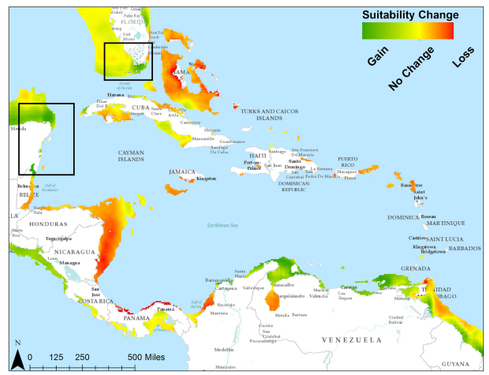
For future scenarios under RCP 4.5, both difference maps indicate a general loss in suitable habitat across the Caribbean region. However, there is a gain in suitable habitat along the **Florida Reef Tract** and **Mesoamerican Barrier Reef System (MBRS)** along the Yucatan Peninsula.

For RCP 8.5, a similar trend of loss and gain occurs across the Caribbean with more extreme rates of loss and gain in suitable habitat.

RCP 4.5 Suitability Change (2070 - 2080)



RCP 8.5 Suitability Change (2070 - 2080)



CONCLUSIONS & SIGNIFICANCE

Our results indicate that both **coral cover and beach width are significantly positively correlated with hotel price.** Our valuation of co-benefits can be used together with risk reduction data from TNC to enable hotels to make informed investment choices in preparation for a changing climate and more frequent and severe storms.

Both our interviews and literature review of cost estimates revealed that **the cost of reef restoration is significantly lower than the cost of grey infrastructure.** The cost model we developed will help hotels project financial return on investments in coral reefs, which is a vital step in incentivizing restoration projects.

We found that there will be an **increase in habitat suitability in all time steps and climate scenarios in certain regions of the Caribbean**, particularly the southern tip of Florida along the Key and the Yucatan Peninsula. Our suitability maps will allow TNC to make strategic decisions to ensure restoration projects implemented today will be successful in the future.

REFERENCES

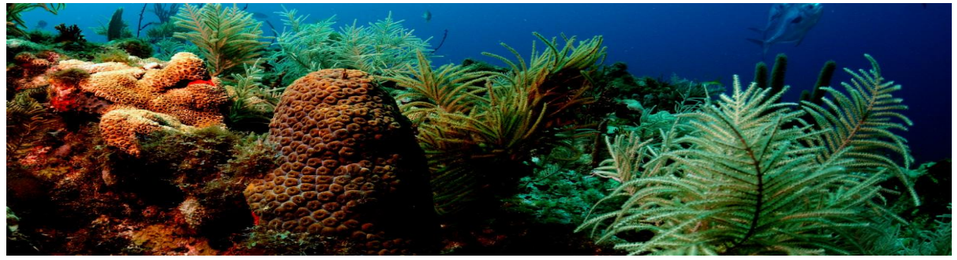
[1]Beck MW, Losada IJ, Menendez P, Reguero BG, Diaz-Simal P, Fernandez F (2018) The global flood protection savings provided by coral reefs. *Nature Communications* 9: 2186. doi: 10.1038/s41467-018-04568-z.

[2]Ferrario F, Beck MW, Storlazzi CD, Micheli F, Shepard CC, Airoldi L (2014) The Effectiveness of Coral Reefs for Coastal Hazard Risk Reduction and Adaptation. *Nature Communications*, 5. *Crossref*, doi:10.1038/ncomms4794.

REEF RESILIENCE | Motivating Investments in Coral Restoration

Mario Colon, Daniel Elkin, Lauren Kaapcke, Madison Meltzer, Casey Moorhead
Faculty Advisors: Ashley Larsen, Samantha Stevenson | PhD Advisor: Juan Carlos Villaseñor-Derbez

Spring 2019 | Project Brief



BRENSCHOOL UC SANTA BARBARA

NATURALLY INSURED

The Nature Conservancy

BACKGROUND & PROJECT SIGNIFICANCE

Coral reefs act as a protective barrier against storms along our coasts, and The Nature Conservancy is leveraging restoration as a method to better protect coastal properties. The field of restoration is growing as governments recognize that many different sectors would benefit from nature-based infrastructure such as coral reefs. We first determined and valued the additional benefits of coral reefs that can be added to the direct flood reduction benefits that reefs provide to incentivize both hotels and insurance companies to contribute to reef restoration. We gathered an estimate of costs associated with restoration and grey infrastructure, and learned which key factors make up the cost of a restoration project. Additionally, we conducted a feasibility analysis to determine where suitable habitat may exist for coral in the future, which could provide The Nature Conservancy with recommendations on where to choose case study sites to apply our cost and benefit methodologies.

THE PROBLEM

- Coastal communities are threatened by storm damage.
- Climate change leads to storms increasing in intensity and frequency, which will also increase coastal property damage.
- Grey infrastructure is the traditional solution to protect vulnerable coastal areas.
- Nature-based solutions are an alternative, but are currently not utilized due to lack of information.

NATURE-BASED SOLUTIONS

- Coral reefs can reduce wave energy by up to 97%.[1]
- Coral reefs protect approximately 258,000 people, US$6 billion dollars of built capital, and 470 km^2 of land from flood damages.[2]
- Coral reefs provide additional benefits such as ecotourism, recreation, fishing, and erosion control.
- Hotels are an industry that benefit from coral reefs and can be targeted for investment.

RESEARCH QUESTION: How do coral co-benefits lead to increases in hotel profit, and where are viable locations for future restoration efforts in the Caribbean?

OBJECTIVES

Objective 1. Develop Approach for Valuing Coral Reef Co-Benefits

Objective 2. Determine Grey and Natural Infrastructure Cost

Objective 3. Identify Future Suitable Habitat for Coral Restoration

ACKNOWLEDGEMENTS

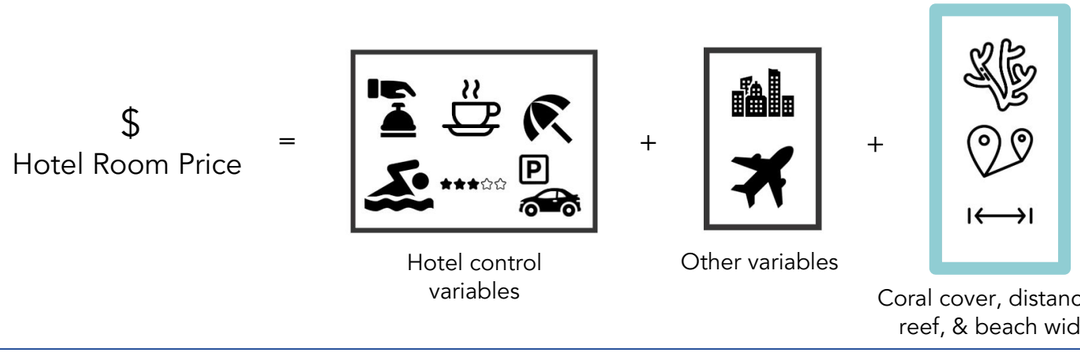
We would like to express our thanks to Mike Beck and Justus Raepple at The Nature Conservancy for serving as clients; our faculty advisors, Ashley Larsen and Samantha Stevenson; our PhD advisor Juan Carlos Villasenor-Derbez; the Bren School; and Chubb for their additional funding support. The team would also like to acknowledge Borja Reguero, Stephan Bitterwolf, and Siddharth Narayan at UC Santa Cruz for their valuable guidance throughout the project.

Regression Analysis

Objective 1. Develop Approach for Valuing Coral Reef Co-Benefits

METHODS

Hotel room price is affected by many variables, such as hotel amenities and location. We performed statistical analysis to find whether and by how much the presence of coral reefs affects hotel room price. Our method values the coral reef co-benefits of ecotourism, measured by coral cover, and erosion control, measured by beach width. We gathered hotel data for 372 hotels in 3 Southeast Florida cities: Fort Lauderdale, Miami Beach, and Key West.



RESULTS

Hotels can expect an additional increase in revenue of $3.97 per 1 km^2 increase in coral cover and $0.37 per 1 m increase in beach width. However, coral cover and beach width were only positively correlated with hotel revenue in Fort Lauderdale. For this reason, we believe our method is most appropriate to apply in locations that are more dependent on reef tourism. In Fort Lauderdale, hotels can expect a:

$34.15 million revenue increase per additional km^2 of coral cover

$1.28 million revenue increase per additional m of beach

Expert Interviews

Objective 2. Determine Grey and Natural Infrastructure Cost

METHODS

We conducted telephone interviews with restoration professionals to discuss the overall costs of their projects. We contacted 18 professionals within 11 different organizations, including NOAA, The World Bank, and the Coral Restoration Foundation. These interviews showed us how restoration cost can vary based on location, organization, and growing and planting technique. From these interviews, we gathered that costs of reef restoration can include project preparation (nursery care, project engineering, and permitting), reef materials (hard costs), labor (outplanting installation, project management, staff training, etc.), and post-implementation costs (monitoring and maintenance costs for X number of years).

NOAA · THE WORLD BANK · CORAL RESTORATION FOUNDATION · MOTE MARINE LABORATORY

Expert Interviews

RESULTS

Based on the information we gathered through these interviews, we developed a model that can estimate the overall cost of a restoration project by aggregating the many smaller components of reef restoration. Our cost model will allow organizations to construct a more accurate total restoration cost without leaving out key components and provide potential investors with a more complete budget for a given project. We created a rough estimate of **$60-90 per m^2 for coral restoration** cost based on the interviews with restoration professionals. Additionally, we contacted the US Army Corps of Engineers (Corps), who are responsible for funding and constructing large grey infrastructure projects along the US coastline. The Corps in Jacksonville, Florida reported an estimate of $6,234 per linear meter of vinyl sheet pile and $7,874 per linear meter of steel sheet pile. The **cost of reef restoration was found to be significantly lower than the cost of grey infrastructure.**

Suitability Analysis

Objective 3. Identify Future Suitable Habitat for Coral Restoration

METHODS

We used the species habitat suitability model program *Maxent* to predict shifts in habitat ranges of future coral species. We compared coral suitability in the Caribbean for three time periods: 2005-2015, 2040 - 2050, and 2070 - 2080 under two climate scenarios: RCP 8.5 (business as usual) and RCP 4.5 (curbed greenhouse gas emissions). *Maxent* predicts coral reef habitat suitability based on coral presence points combined with five important environmental variables that change in current and future climate scenarios.

Environmental Variables

Maxent Species Distribution Model