Introduction: Coral reefs have declined globally with coral cover in the Caribbean Sea declining approximately 80% from the 1970s to the early 2000s[1] primarily due to a combination of global-scale thermal and CO_2-induced stressors and local-scale overfishing, pollution, human population increases, invasive species, coral disease, and storms[2]. A recent synthesis report recommends an increase in local management strategies to reduce local stressors and emphasizes the importance of herbivorous parrotfishes to protect the overall health of coral reefs[2]. Marine Protected Areas (MPAs) are frequently celebrated as a tool for maintaining sustainable fisheries with evidence suggesting that the increased abundances of herbivorous fishes in MPAs may facilitate coral recruitment via a trophic cascade effect[3]. Despite this finding, there is a dearth in the literature investigating this MPA trophic cascade with many studies failing to find a correlation between the sole determinant of coral coverage and MPA status[4,5]. However, due to a stress-induced selection for less structurally complex, hardier coral species[6], it is necessary to investigate shifts in coral species composition and coral-derived reef structural complexity that are likely to occur with important implications for reef biodiversity, habitat creation, and overall reef system function. The research goal of this proposed study is therefore to better determine how no-take MPAs impact reef system function and structure to improve the use of MPAs for the conservation of coral reef ecosystems and the services they provide.

Hypotheses:

(1) Sites located within MPAs will yield higher coral recruitment, more diverse coral species composition, and higher structural complexity than non-protected areas due to trophic cascades resulting from higher abundances of herbivorous reef fishes.

(2) Sites located along the interior perimeter of the MPA will have lower coral recruitment, less diverse coral species composition, and lower structural complexity than sites located in the center of the MPA due to edge-effects[7] created by increased fishing pressure and lower abundances of herbivorous reef fishes at the MPA boundary.

Experimental Approach:

Site Selection: It is important to select study sites of similar non-fishing stress profiles to best isolate the trophic cascade effect of MPAs in the Caribbean basin. I will layer publically available datasets for organic pollution, inorganic pollution, ocean based pollution, population pressure, nutrient input, invasive species, ocean acidification, and sea surface temperature anomalies[8] using ArcGIS software to produce a unique composite non-fishing anthropogenic stress map of the Caribbean basin. Using this map, I will then be able to locate regions of similarly low stress profiles that overlap with existing coral reef MPAs to select six study sites. Three reef locations in the same reef zone with approximately the same depth will be randomly selected from locations near the center of each MPA, along the interior perimeter of each MPA, and outside the boundaries of each MPA for a total of 9 reef locations per MPA study site.

Data Collection: Three transects documenting coral species composition, abundance, and size at each location will be recorded utilizing video transects and parrotfish counts will be conducted by diver visual surveys following AGGRA rapid assessment protocols[9]. Coral recruitment will be expressed by the number of coral individuals with size < 20 cm^2 per unit area[3]. Structural complexity will be quantified for each site using light detection and ranging (LIDAR) for accurate large scale modeling and estimation of reef structural complexity[10].

Data Synthesis: Average coral recruitment, species composition, structural complexity, and parrotfish counts of reef site locations near the center, along the perimeter, and outside each MPA can then be compared using statistical models to test for a trophic cascade effect on the three components of reef health resulting from the presence of herbivorous parrotfishes within (Hypothesis 1) and along the interior perimeters (Hypothesis 2) of MPAs.

Intellectual Merit: This study will be the first to incorporate reef structural complexity into the coral reef MPA trophic cascade effect while further exploring changes in coral species composition to determine if MPAs are impacting coral reef ecosystem function beyond coral recruitment. By applying the terrestrial-ecology inspired analysis of edge-effects beyond reef fishes to trophic cascade effects on corals, this study further expands on theoretical ecological knowledge of edge-effects represented by potential changes in the three metrics of coral recruitment, composition, and structural complexity along the MPA boundary. This analysis of MPA driven trophic cascade effects on coral reefs in lower stress regions could yield significant insight into how MPAs can be used to conserve coral reef ecosystems and what shape those reefs may take when protected from fishing pressures in an era of increasing global climatic stressors.

Broader Impacts: This research will better determine whether MPA driven trophic cascade effects impact coral recruitment, coral species composition, and structural complexity in an era of anthropogenic and climate driven reef stress. These findings could have potentially large impacts for how local MPA policy could be structured for the goals of holistic coral reef conservation as opposed to more common fisheries-based MPAs. It will also provide a publicly available non-fishing anthropogenic stress map that can serve as an effective site-selection tool for policy makers and island communities to design more efficient and effective networks of MPAs across the Caribbean in the future. Local scientific aids will be recruited to aid in quantifying the reef habitat parameters at each site for improved local understanding of the importance of MPAs. I will author manuscripts for publication in peer-reviewed scientific journals and present my findings at scientific conferences. These research findings will also be made publically available outside of the scientific community through the use of internet social media. I will continue my personal commitment to use my skills and available resources to recruit, develop, and mentor undergraduates as scientists and educators. I will collaborate with local K-12 public school teachers to integrate this work into targeted cross-discipline lesson plans they can use to apply cutting-edge science research in their curriculums to promote youth environmental involvement.

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