Evaluating coral reef resilience in the context of global bleaching

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Introduction: Coral reefs shelter 25% of all marine species[1] and provide food, protect coastlines, and support economic opportunities for over 1 billion people worldwide.[2] However, coral reefs face multiple threats. Chronic stressors, including overfishing, coastal development, pollution, and ocean acidification, slowly degrade coral reefs by undermining vital ecological processes, such as grazing by reef fish and coral growth.[3] Coral reefs are also threatened by acute stressors, such as cyclones and coral bleaching events, that may severely damage or restructure coral reef ecosystems.[2,3] Climate change is predicted to compound these stressors and has already increased average ocean temperatures by 0.9°C globally.[4] This increase has triggered three global bleaching events to date, and most coral reefs are projected to face annual bleaching by the 2050s.[4]

Adaptive and innovative management approaches are needed to ensure the longevity of coral reef communities in an era of global change.[5] One potential approach supported by an emerging body of research[3, 5-13] is resilience-based management (RBM).[7] Under RBM, scientists and coral reef managers use a variety of biotic and abiotic indicators to assess coral reef resilience, where resilience is defined as the capacity of an ecosystem to resist and recover from stress without shifting to a less desirable ecosystem state.[6] However, several knowledge gaps related to coral reef resilience hinder application of RBM theory.[5-12] Scientists have not reached consensus on which biotic and abiotic indicators are the strongest drivers of coral reef resilience.[6, 8] Most assessments of coral reef resilience are predictive, and few studies exist that test the accuracy of these predictions following major stress events.[6, 13] Furthermore, these assessments are conducted across a range of geographies using varying methodologies, [5-12] which makes it difficult determine if observed variability in resilience is due to context-specific factors or broad biogeographic patterns. In addition, assessments of coral reef resilience are still evolving to incorporate emerging science on ecosystem thresholds and phase shifts between coral- and algal-dominated states.[3, 11, 13]

Proposed Research: The destructive 2014–2017 global bleaching event (Event), which impacted 51% of the world's coral reefs,[14] presents a unique opportunity to examine the impacts of major stress events on coral reef resilience. By evaluating changes in coral reef condition across an array of sites before, during, and after the Event, I will (1) assess the relative importance of select biotic and abiotic factors in determining coral reef resilience, (2) examine how the importance of these factors varies spatially among reefs in the central Pacific, and (3) ground-truth existing methods used to predict coral reef resilience.

Experimental Design: An effective analysis of coral reef resistance to, and recovery from the Event will require extensive monitoring data that documents biotic and abiotic conditions on coral reefs before, during, and after the Event. As a graduate researcher at the Scripps Institute of Oceanography (SIO), I will be well positioned to access comprehensive monitoring data from past studies and collect data through current monitoring programs.

To evaluate coral reef condition before the Event, I will analyze benthic and reef fish monitoring data collected as part of an extensive SIO study that monitored coral reefs across 56 islands in the central Pacific from 2002–2009.[15] To assess coral reef resilience during and after the Event, I will analyze photo surveys and fish transect data collected as part of the 100 Island Challenge (Challenge), which is currently surveying 100 islands across a range of environmental and anthropogenic gradients in the Pacific and Caribbean.[16] Photo surveys collected as part of the Challenge are orthoprojected to generate comprehensive 3D models of the coral reef benthos that document species composition and spatial arrangement to a resolution of $1cm^2$. The Challenge surveys sites (many of which were affected by the Event)[14, 16] at regular intervals to document ecological changes, and has been monitoring numerous islands since 2013.

I will select study sites by cross-referencing monitoring locations from the 2002–2009 study[15] with locations currently being monitored by the Challenge (I anticipate this will reveal several dozen sites with sufficient monitoring data). I will evaluate the historic exposure of study sites to chronic stressors using the World Resources Institute's Reefs at Risk spatial dataset of anthropogenic impacts.[9] Similarly, I will evaluate historic exposure to acute stressors before the Event, and bleaching alert levels during the Event, using spatial data produced by NOAA's Coral Reef Watch. Based on this evaluation, I will classify sites into eight experimental groups (Fig. 1).

I will build off existing meta-analyses of RBM studies[6, 12] to identify priority resilience indicators to measure, such as coral cover/diversity, herbivore biomass/diversity, coral recruitment, coral disease, macroalgae cover, bioerosion, substrate availability, and topographic complexity.[3, 5-12] I will monitor these indicators as a member of the Challenge research team and extract relevant data from the 2002-2009 SIO monitoring dataset.[15] Using this data, I will generate site-level averages for each indicator before the Event to determine baseline conditions and analyze indicator variance to assess pre-bleaching trends in ecosystem health. I will compare these values to indicator averages and variance after the Event to identify indicators with a statistically significant impact on coral reef resistance to and recovery from bleaching. I will also analyze spatial variability in site resilience to detect regional or context specific patterns (i.e., which indicators determine resilience and where), a knowledge gap prior studies have not addressed. Lastly, I will examine areas of overlap and divergence between my findings and those of prior resilience assessments.

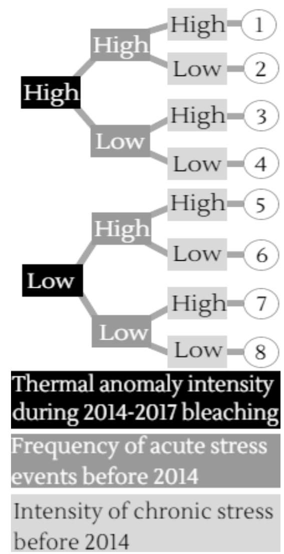

Fig. 1: Sites will be classed into 8 groups based on past exposure.

Anticipated Results: I hypothesize that reef resilience will vary depending on each site's history of chronic and acute stress exposure. In addition, I anticipate that the accuracy of resilience predictions and the relative importance of biotic and abiotic drivers of resilience will exhibit spatial variability at regional and local scales.

Intellectual Merit and Broader Impacts: This study will ground-truth RBM theory using empirical data to analyze patterns of coral reef resilience before, during, and after a major environmental disturbance. As a co-author of an RBM study,[9] I recognize the potential of this research to address knowledge gaps, and thereby enable scientists to further refine RBM methods to reflect observed patterns of coral reef resilience. This continued refinement will be critical[6] as reef managers, communities, and governments move to adopt RBM to inform marine protected area design, fisheries regulations, and other conservation measures[7-10] that would have broad impacts for millions of people who depend on coral reef ecosystems.[2] In addition, the methods outlined in this study could be modified to test RBM assumptions for other ecosystems threatened by climate change.[7] As I conduct this research, I will use connections I have cultivated in the marine non-profit community by collaborating with researchers and practitioners, and draw from my communications experience as an environmental blogger to widely disseminate my findings.

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