Resilience in a coral reef ecosystem: Initiation of a long-term experiment to determine the effects of multiple disturbances

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Background

Documenting the trajectories of ecological communities following a disturbance represents one of the five core research themes central to LTER network science. Quantifying degrees of resilience, here defined as the time needed for a community to return to a previous steady or quasi-steady state following a disturbance, can be especially challenging when ecosystems experience multiple perturbations that, in combination, can cause complex, non-linear community responses. Understanding what influences resilience is becoming ever more critical in light of forecasted alterations in disturbance regimes (pulse events) and environmental drivers (press events) associated with global climate change. Global environmental change not only is altering the intensity of press events, it also is changing the frequency and strength of pulse disturbances. Given these complexities, the ability to forecast how ecosystems will respond to or recover from projected changes in pulse and press events is an important scientific challenge.

An unanticipated natural disturbance that is now occurring at the Moorea Coral Reef LTER site provides an opportunity to resolve several key questions regarding resilience, including the trajectory of the system following disturbances that affect different components of the ecosystem, and the existence and strength of positive feedbacks that might produce alternate persistent states. The source of the current disturbance is an outbreak of crown-of-thorns sea stars on the reefs surrounding Moorea that has reduced the cover of living coral from ~60% to ~5% cover over large areas (Figure 1). The widespread elimination of just living coral tissue (with coral skeletal structure left intact) provides an opportunity to manipulate additional features to mimic qualitatively different types of disturbances (pulses), and to cross these treatments with various combinations of other environmental stressors (presses). MCR investigators will conduct surveys and carry out a large field experiment to explore how and why resilience is affected by structural heterogeneity, grazing, corallivory and composition of the microbial community.

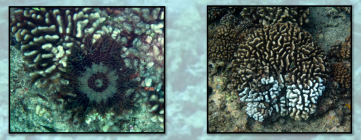

Figure 1: LEFT - The crown-of-thorns sea star (*Acanthaster planci*) RIGHT- Removal of live coral tissue leaves behind a large feeding scar (white area). Whole colonies can be quickly consumed, leaving behind the dead skeletal structure

The System

The coral reefs surrounding the island of Moorea, French Polynesia (Figure 2) are typical of coral dominated ecosystems located in the South Pacific and other tropical regions throughout the world.

Figure 2: Moorea, French Polynesia (17˚30˚S, 149˚50˚W). Experimental plots were established at a depth of 13m on the fore reef along the northern shore of the island (red box in photo).

Prior to the current outbreak of the crown-of-thorns sea star, the majority of the reef surrounding Moorea was covered primarily with a mixture of living Acroporid, Pocilloporid, and Poritid corals (Figure 3A). Since the outbreak, the cover of live coral in large areas of the fore reef has been reduced greatly (Figure 3B).

Figure 3: The total cover of live coral in large areas of the fore reef has declined dramatically following the most recent outbreak of the crown-of-thorns sea star. Live coral cover fell from an average of 60-70% in 2006 (A) to less than 5% in 2009 (B).

The Experiment

Twenty 5m x 5m plots were established in an area of the fore reef on the north shore of Moorea (Figure 2). All plots were permanently marked (Figure 4A & B) and photographed (Figure 4C) at two scales; 0.25m^2 and 0.01m^2 (Figure 4D & E).

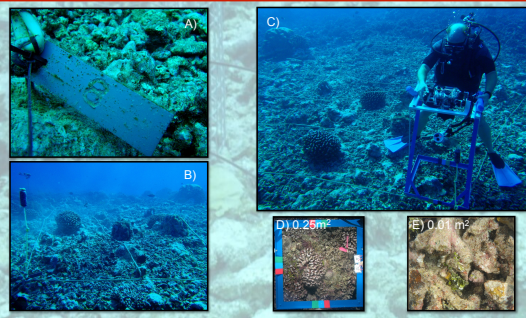

Figure 4: Experimental plots were marked permanently using eye bolts fixed into the reef (A). Floats (B) aided divers in relocating plots. Grid lines (B & C) were laid out within each plot to permanently assign a location to each photograph taken at the larger of the two spatial scales (C). Plots will be re-photographed over time to look for changes in the cover of both foliose and crustose coralline algae. Photos at both spatial scales (D & E) showed the presence of these two algal types (CCA=pink, foliose=green).

Adjacent plots were grouped into pairs. Divers using SCUBA then removed all dead coral structure from one randomly selected plot within each pair (Figure 5A). Removal of the dead coral structure simulates the type of disturbance commonly associated with the of effects of a hurricane, i.e. the loss of structural heterogeneity from the reef. An additional 1 m border around each structural removal plot was cleared of all dead coral in an attempt to minimize edge effects from within the central 5m x 5m plots (Figure 5B). The ten manipulated plots were re-photographed following the removal of all dead coral structure.

Surveys of fishes and non-coral macroinvertebrates were performed on each plot in both the before and after structural removal periods. Abundance and percent cover of corals, CCA and foliose algae will be estimated from photographs. Water samples were taken from the water column, just above the substrate and from the interstitial spaces within each plot to enable the characterization of the microbial community present at the initiation of the experiment.

Nine sets of coral settlement tiles (Figure 6A) were placed randomly within each plot. Wire mesh cages 0.75m^2 in area and made of hardware cloth (mesh = 2.5 cm) were placed over three randomly chosen sets of coral settlement tiles within each plot (Figure 6B). Cages are intended to exclude herbivores and coralivores (mainly fishes and urchins) in an attempt to mimic the effects of over-fishing on these species. Half cages were placed over an additional three sets of randomly selected tiles within each plot to control for possible effects of differing light levels or water velocities within the cages. The remaining three sets of settlement tiles within each plot were left exposed to herbivores and coralivores..

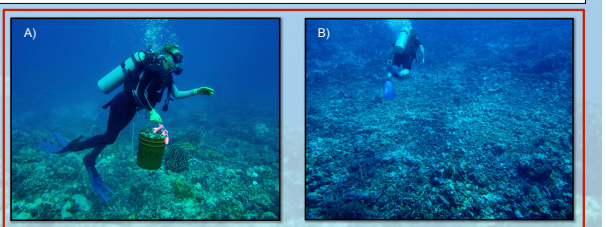

Figure 5: Divers using buckets remove all dead coral structure from half of the twenty 5m x 5m plots (A). Removal of the dead coral skeletons is intended to mimic the effects of a hurricane that results in a large scale decline in the overall structural heterogeneity of the reef (B).

Utilizing this experimental design, MCR investigators will be able to assess the degree of ecosystem resilience exhibited by a typical coral reef to two commonly experienced pulse disturbances affecting reefs throughout the tropical Pacific: periodic outbreaks of the crown-of-thorns sea star that eliminate live coral tissue, but leave the dead coral skeletons intact (Figure 7A) and the associated effects of hurricanes that reduce most corals to rubble and decrease reef structural complexity (Figure 7B). These two pulse disturbances are, in turn, crossed with a simulated, longer-term, press disturbance in the form of reduced herbivory and coralivory by fishes and urchins.

Manipulations can be made within the remaining, open areas of the plots, enabling additional hypotheses to be tested by future LTER investigators.

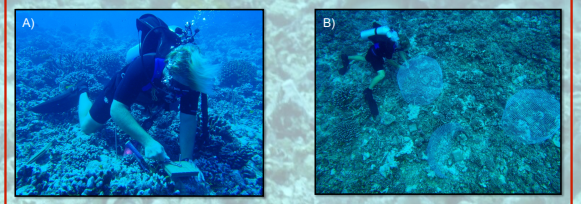

Figure 6: Seasoned, terra cotta tiles are deployed within the experimental plots as standardized coral settlement substrate (A). Tiles are bolted onto threaded posts permanently affixed to the reef. Wire mesh cages (B) are placed over three of the nine sets of tiles deployed within each plot to exclude herbivores and coralivorus fishes and urchins. Half cages serve as cage controls for possible artifacts involving decreased light levels or water velocity.

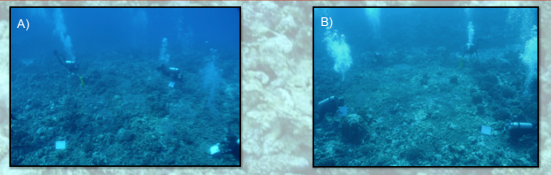

Figure 7: Plots containing dead coral skeletons (A) and those with reduced structural heterogeneity following removal of the dead coral colonies (B). Exclusion cages, cage controls and coral settlement plates can be seen on both plots.

Acknowledgments

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For further information

More information on this and other related projects can be obtained from ***http://mcr.lternet.edu*** or by e-mailing Dr. Andrew Brooks at ***brooks@msi.ucsb.edu***