For the past 6 years, the University of Puerto Rico has led a multidisciplinary study of Coral Reefs in the US Caribbean. Entitled "Coral Reef Ecosystems Studies (CRES): Integrating Science & Management in the Caribbean", the study was supported by NOAA's Center for Sponsored Coastal Ocean Research, with a total funding level of $5 million. Primary academic and federal partners were the

- University of Puerto Rico
- University of Miami
- Island Resources Foundation
- University of South Carolina
- NOS – Centers for Coastal Monitoring and Assessment
- NMFS – Galveston Laboratory
- USGS – Biological Resources Division

The overall of objectives of the PR CRES program were to (1) study the processes responsible for decline in coral reefs, (2) study the feasibility of alternative management strategies, and (3) offer practical management advice and tools. The primary research site was La Paguera, on the southwest coast of Puerto Rico; additional work was conducted at the Luis Peña Canal Marine Reserve off Culebra Island, PR and in St. John, USVI, including the newly established coral monument.

This past February 11-13, a symposium was held in La Parguera, Puerto Rico to present the results of the PR CRES program. My purpose here is to highlight what we learned during the CRES program, and the initial results are disturbing. During the project, live coral cover was reduced by 50% (see, e.g., Figure 1). This loss was consistent across all locations.
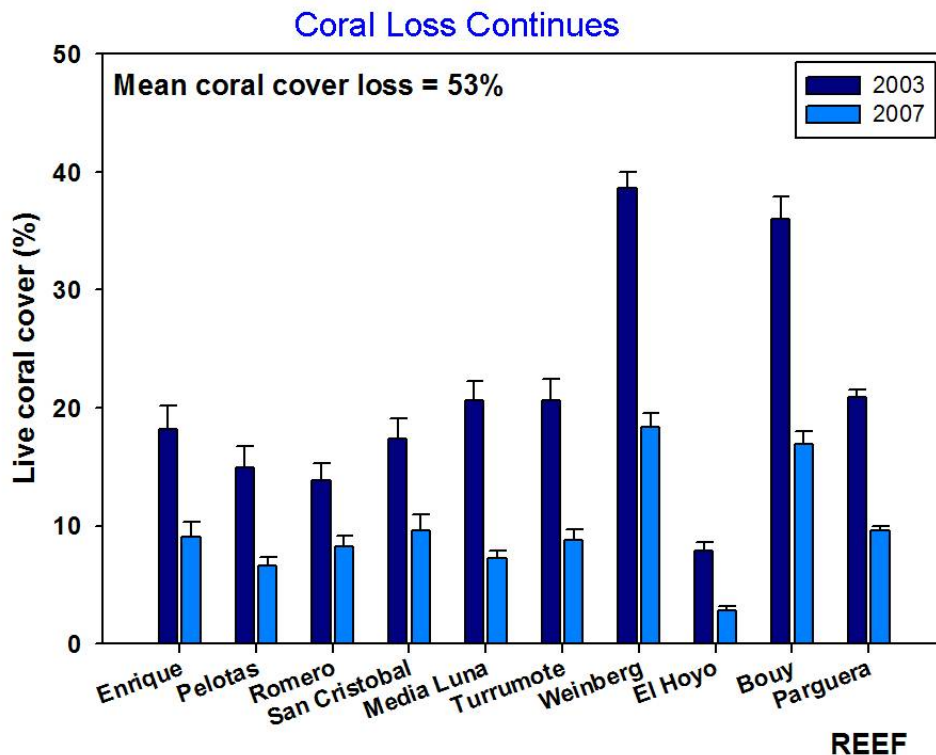

Figure 1. Live coral loss at 9 reefs in La Parguera PR from 2003-2009.

The primary immediate cause of coral mortality was the 2005 bleaching and disease event, where unprecedented bleaching caused by high water temperature was immediately followed by disease outbreaks. The even led to no only loss of live coral cover, but also resulted in reproductive failure in important reef building corals that extended into the following years.

The severity of the bleaching event points to the impact of global warming, but the impacts of the latter are more complex and serious. As seen in Figure 2, there is a direct correlation with the prevalence of the disease and water temperature.
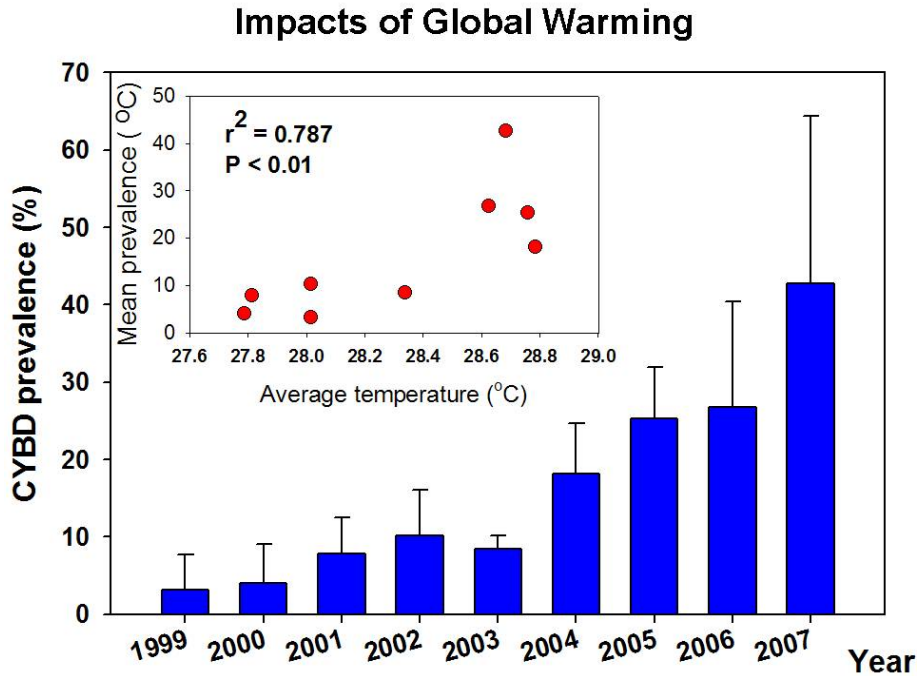

Figure 2. Relationship between the prevalence of Caribbean yellow-band disease and the water temperature in La Parguera, PR

Most serious has been the increase in minimum temperature. In past years, low winter temperature would cause remission of the disease, giving the corals a period to recover. With rising winter temperatures, the remission period now no longer occurs, causing excessive stress and leading to enhanced mortality.

As distressing as this event was, longer term observations show that the decline is part of a longer term trend (Figure 3). An inverse of the decline of coral cover depicted in Figure 3 is the rise of algal cover, particularly by cyanobacteria. The CRES program was able to document the initiation of summer blooms of cyanobacteria at the least disturbed, shelf-edge reefs of La Parguera, which previously had not been observed. Initially, as with disease, low winter temperature cause a die-off of cyanobacteria and provided a period of recovery for corals. As temperatures increased, the overgrowth by cyanobacteria and other algae was sustained throughout the year, resulting in the smothering of corals.
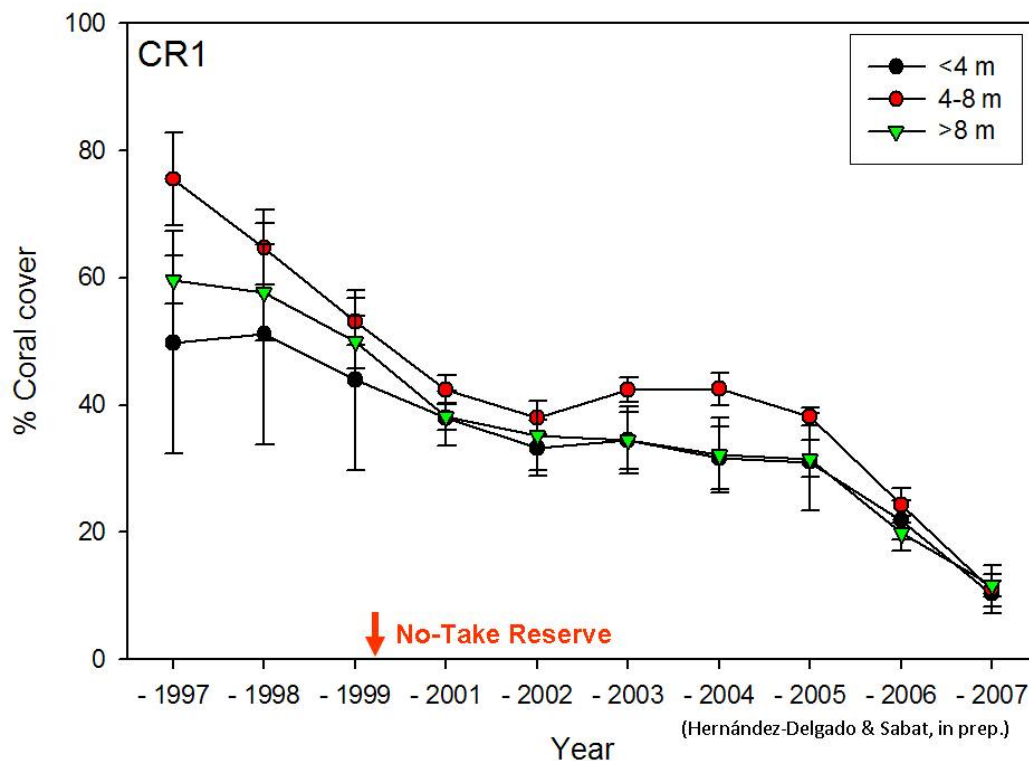
Figure 3. Trends in % live coral cover within the Luis Peña Canal Marine Reserve at three depths.

Additional significant findings of the CRES project were;

• The important groups constituting reef communities (corals, gorgonians, algae, fish) all respond differently in space and time. This will affect how reef health is defined and the expected impacts to either threats or management interventions.

• Detailed studies of the input and distribution of sediments and nutrients into the La Parguera system, as well as current flows, showed that inputs from the immediate La Parguera watershed were normally constrained to nearshore waters, affecting primarily the inner reefs only. Inputs to the shelf-edge, outer shelf, and outer emergent reefs come primarily for upstream sources to the east. This illustrates the importance of defining the appropriate watershed when targeting watershed management to conserve coral reefs.

An assessment of local threats showed that sedimentation was increasing overtime due to increased coastal development, and the increased turbidity was a serious problem. Light reaching shelf-edge corals at 25 m depth was actually greater than that reaching shallow near-shore corals. Related studies have shown that increased turbidity negative impacts both coral cover and fish diversity. Only resistant corals were abundant on inshore reefs.

While contaminants were generally low of La Parguera, this would not be expected elsewhere. Furthermore, there was new evidence that unusual contaminants, such as the estrogen mimics can have serious impact on corals. This may occur in locations with high tourist traffic (e.g., Trunk Bay, USVI) due to such contaminants found in some sunscreens.

One of the most serious local threats is the loss of herbivory (to control algal growth) due to the die off of the long-spined sea urchin in the 1980's and the disruption of trophic systems caused by overfishing. Algae harm corals by overgrowing live corals, by overgrowing space needed for coral recruitment, and by producing allelopathic substances that affect coral health. Fish herbivory has been drastically altered by a reductions in the number of herbiores, the size of herbivores and the types of herbivores.

A particular focus of the PR CRES project was the examination of marine reserves (No-take Marine Protected Areas) as a management tool to help restore reef communities. Marine reserves are a proven way to help restore exploited species, and they are critical for providing baseline information to assess the impacts of fishing and other stressors to coral reefs. Results show, however, that science needs play an important role in reserve design and implementation. Results additionally show that governance systems are as equally important for the success of any reserved. Governance systems will need to adapt and evolve if corals are to be protected from external stressors, adequately engages stakeholders and enact effective enforcement and compliance.

Equally important, the PR CRES program highlighted critical areas where we do not have sufficient information. This includes the information on the life histories and ecology of ecologically important taxa (e.g., invertebrates, herbivorous fishes, algae, etc.), and on ecological processes and interactions (e.g., the relationship between coral settlement, survival and adult densities, or the relationship between stress, microbial communities and coral disease).

Lastly, the PR CRES project is producing several Management Tools. These include a Decision Support System, a MPA trophic model for assessing MPA ecological effectivness, a fisheries assessment model, and a water-flow model. Additionally, the results of the PR CRES project have already acted as a seed for other developments in support of management. These include
- an extension of the sediment production research to produce a GIS model to estimate sediment production and islolate problem areas (funded by the Caribbean Coral Reef Institute (CCRI))
- the establishment of protocols for developing MPA management plans (CCRI funded) and their subsequent application for MPAs in Culebra, Rincon and soon in La Parguera, PR
- the alterations of zoning boundaries at the Mona Island MPA to protect threatened groupers spawning aggregations
- the development of passive acoustic techniques for monitoring fish spawning aggregations (CCRI funded).

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